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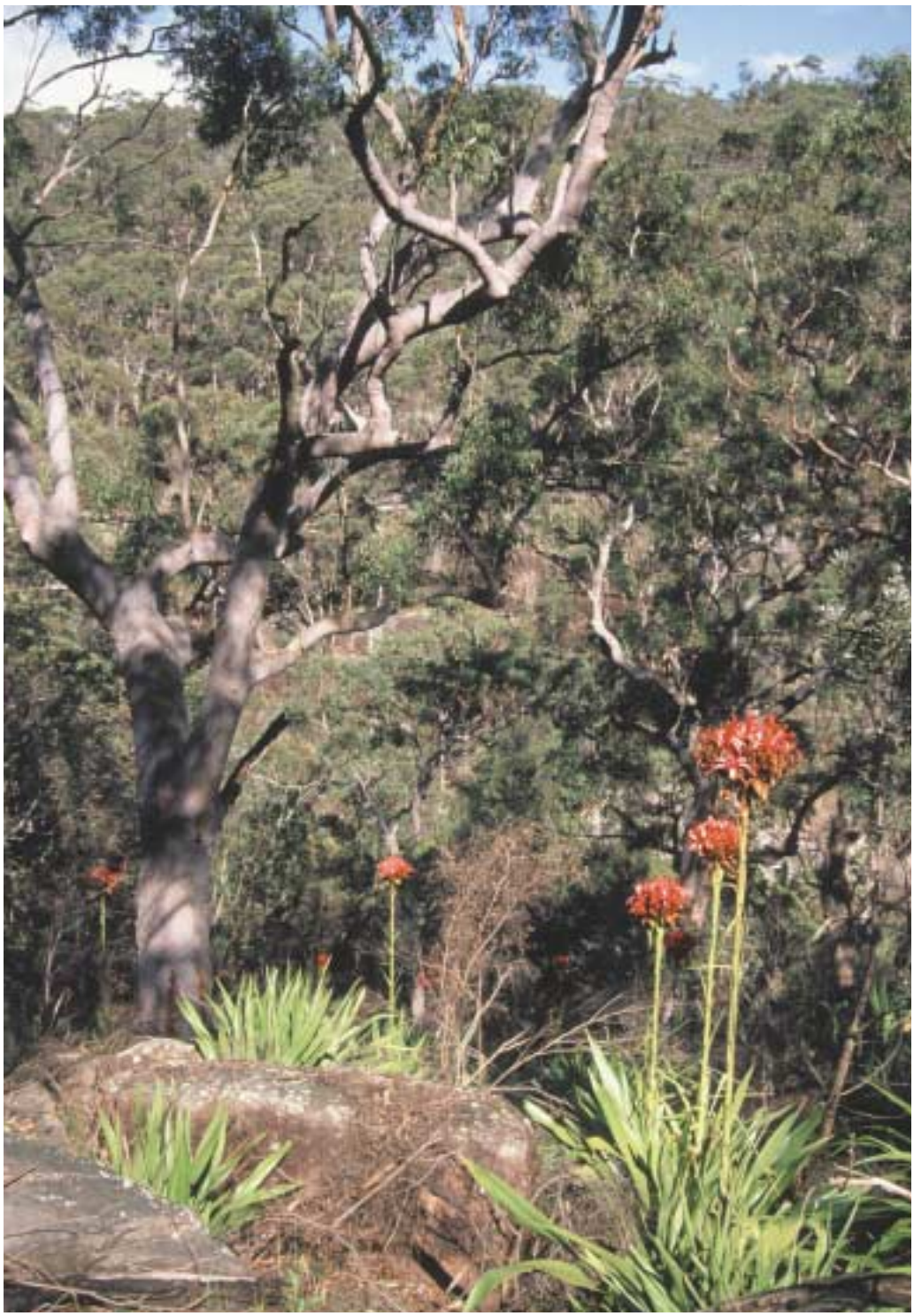
Environmental and Effluent Monitoring at ANSTO Sites

2003-2004



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Contact Details

ANSTO	Australian Nuclear Science and Technology Organisation New Illawarra Road, Lucas Heights, NSW, Australia
Postal Address	Private Mail Bag 1 Menai NSW 2234, Australia
Telephone	+ 61 2 9717 3111
Facsimile	+ 61 2 9543 5097
Email	enquiries@ansto.gov.au
Internet	www.ansto.gov.au

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Environmental and Effluent Monitoring at ANSTO Sites, 2003–2004

Emmy L Hoffmann, John M Ferris, Jennifer J Harrison, Tom Loosz

Abstract

This report presents the results of ANSTO's environmental and effluent monitoring at the Lucas Heights Science and Technology Centre (LHSTC) and the National Medical Cyclotron (NMC) sites, from July 2003 to June 2004. Effective doses to the critical group of members of the public potentially affected by routine airborne emissions from the LHSTC were less than 0.004 mSv/year. This estimated maximum potential dose is less than 20% of the ANSTO ALARA objective of 0.02 mSv/year and much lower than the public dose limit of 1 mSv/year that is recommended by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). The effective doses to the critical group of members of the public potentially exposed to routine liquid effluent releases from the LHSTC have been realistically estimated as a quarter (or less) of the estimated doses to the critical group for airborne releases. The levels of tritium detected in groundwater and stormwater at the LHSTC were less than the Australian Drinking Water Guidelines. The airborne and liquid effluent emissions from the NMC were below the ARPANSA-approved notification levels and NSW Department of Environment and Conservation limits, respectively. Results of environmental monitoring at both ANSTO sites confirm that the facilities continue to be operated well within regulatory limits. Members of the public are exposed to only very small doses of radiation from ANSTO's routine airborne and liquid effluent releases.

INIS Descriptors

The following descriptors have been selected from the INIS Thesaurus to describe the subject matter of this report for information retrieval purposes. For further details please refer to IAEA-INIS-12 (INIS Manual for Indexing) and IAEA-INIS-13 (INIS Thesaurus) published in Vienna by the International Atomic Energy Agency. Airborne Particulates, Algae, Alpha Decay Radioisotopes, Alpha Particles, ANSTO, Argon-41, Arsenic-76, Australia, Beryllium-7, Bromine-82, Cerium-144, Caesium-134, Caesium-137, Chromium-51, Cobalt-57, Cobalt-60, Contamination, Cyclotrons, Dose-Constraint, Dose Limits, Drinking Water, Environmental Exposure Pathway, Environmental Impacts, Fishes, Fission Product Release, Fluorine-18, Gallium-67, Gaseous Wastes, Ground Water, Iodine-123, Iodine-131, Iodine-132, Iodine-133, Krypton-85m, Lead-201, Lead-210, Liquid Wastes, Mercury-197, Mercury-203, Molybdenum-99 Niobium-95, Noble Gases, Public Health, Radiation Doses, Radiation Monitoring, Radioactive Effluents, Radium-226, Radium-228, Ruthenium-103, Ruthenium-106, Sampling, Seawater, Sediments, Soils, Stack Disposal, Standards, Strontium-90, Surface Waters, Thallium-201, Thallium-202, Thermoluminescent Dosimetry, Tritium, Uranium-238, Water Quality, Wind, Xenon-133, Xenon-135, Xenon-135m, Zinc-65, Zirconium-95.

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SI UNITS

Quantity	SI Unit and Abbreviation
Absorbed Dose	Gray (Gy)
Dose Equivalent	Sievert (Sv)
Radioactivity	Becquerel (Bq)

Multiples And Submultiples Of SI Units

10^{3}	kilo (k)	10^{-3}	milli (m)
10^{6}	mega (M)	10^{-6}	micro (µ)
10^{9}	giga (G)	10^{-9}	nano (n)
10^{12}	tera (T)	10^{-12}	pico (p)

LIST OF ABBREVIATIONS

AAEC	The former Australian Atomic Energy Commission, now ANSTO
ADWG	Australian Drinking Water Guidelines
ALARA	As Low As Reasonably Achievable
ANSTO	Australian Nuclear Science and Technology Organisation
ARI	Australian Radiopharmaceuticals and Industrials
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
ASP	Aerosol Sampling Program
DEC	NSW Department of Environment and Conservation
EMP	Environmental Management Plan
EMS	Environmental Management System
EPA	Environment Protection Authority (incorporated into the DEC in Sept. 2003)
HEPA	High Efficiency Particulate Air filter
HIFAR	High Flux Australian Reactor
IAEA	International Atomic Energy Agency
ICPMS	Inductively Coupled Plasma Mass Spectrometry
ICRP	International Commission on Radiological Protection
INIS	International Nuclear Information System
IQR	Interquartile Range (range from 25^{th} to 75^{th} percentile)
ISO	International Organisation for Standardisation
LFBG	Little Forest Burial Ground
LH	Lucas Heights
LHSTC	Lucas Heights Science and Technology Centre
MDA	Minimum Detectable Activity
MDP	Main Discharge Pipeline
NHMRC	National Health and Medical Research Council
NMC	National Medical Cyclotron
NOHSC	National Occupational Health and Safety Commission
NSW	New South Wales
PM	Particulate Matter
RRR	Replacement Research Reactor
SI	Système International d'Unite
SPCC	The former State Pollution Control Commission (which became the NSW EPA, now the NSW DEC)
STP	Sewage Treatment Plant
TLD	Thermo-luminescent Dosimeters
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation

1. Introduction

The Australian Nuclear Science and Technology Organisation (ANSTO) operates several national facilities, including Australia's research reactor, HIFAR (the High Flux Australian Reactor), produces radioisotopes and radiopharmaceuticals and carries out research in nuclear science and technology. ANSTO is an agency of the Commonwealth Government of Australia. Most of the ANSTO facilities are located at the Lucas Heights Science and Technology Centre (LHSTC), some 40 km south-west of the Sydney city centre. The LHSTC occupies 70 hectares and is surrounded by a 1.6 km diameter buffer zone (**Figure 1**, see section 5). ANSTO also operates the National Medical Cyclotron (NMC), located in Camperdown, Sydney, to produce certain short-lived radioisotopes for medical investigations. ANSTO's activities are regulated by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) under the *Australian Radiation Protection and Nuclear Safety Act* 1998.

ANSTO is committed to undertaking its activities in a manner that protects the environment and is consistent with national and international standards. ANSTO promotes environmental awareness throughout all levels of the organisation, and strives for continual improvement in environmental performance. As part of its commitment to environmental protection, ANSTO is implementing an Environmental Management System (EMS) that gained certification to the international standard ISO14001 in 2004. The program for achieving the EMS objectives is documented in a series of Environmental Management Plans (EMPs), which cover airborne emissions, radioactive wastes, surface waters, groundwater, resource usage and management of the Little Forest Burial Ground (LFBG). ANSTO provides verifiable evidence of its environmental performance through an audited program of environmental monitoring, and publication of these results in this report and others in the annual Environmental and Effluent Monitoring series.

This report summarises the results from the environmental and effluent monitoring carried out at the LHSTC and the NMC from July 2003 to June 2004, and assesses the potential effects of radioactive discharges, with particular emphasis on local residents. Data published in previous years are publicly available either from the Sutherland Shire Central Library or by request from ANSTO's Communications Manager.

2. ANSTO Facilities

2.1 HIFAR

The HIFAR research reactor produces radioisotopes for medical and industrial use and employs neutrons for research applications. HIFAR is authorised by ARPANSA to release low levels of radionuclides to the atmosphere via stacks. The main radionuclides are tritium and argon-41 (a noble gas). There are also small quantities of iodine-131, arsenic-76, bromine-82, mercury-197 and mercury-203. The tritium occurs as tritiated water vapour that can exchange with rainwater, resulting in the presence of tritium in local surface waters and groundwater at concentrations somewhat above the normal background for Australian waters. Low-level liquid waste is treated and discharged via the Sydney Water Corporation sewer under the terms of a trade wastewater agreement.

2.2 RADIOISOTOPE PRODUCTION

The production of radioisotopes for medical and industrial use by ANSTO Radiopharmaceuticals and Industrials (ARI) results in the release of small quantities of radionuclides to the environment from the LHSTC. ARPANSA regulates the atmospheric releases of radionuclides including iodine-131, xenon-133, xenon-135 and krypton-85 from stacks in the radioisotope and radiopharmaceutical production area at the LHSTC. Low-level liquid waste is treated and discharged via the Sydney Water Corporation sewer under the terms of a trade wastewater agreement.

2.3 NATIONAL MEDICAL CYCLOTRON

ANSTO also manufactures radiopharmaceuticals at the NMC (Camperdown, Sydney). The major

radiopharmaceutical products made at the NMC in 2003-04 were thallium-201, gallium-67, iodine-123 and fluorine-18, all of which have relatively short half-lives ranging from minutes to hours. The radionuclides that may be present in liquid effluent produced by the NMC include thallium-201, thallium-202, gallium-67, cobalt-57, zinc-65, iodine-123, lead-201 and fluorine-18. However, a system of delayed liquid effluent releases allows the radionuclides to decay significantly prior to being released to the sewer; consequently, lead-201 (half-life 9.3 hours) and fluorine-18 (half-life 110 minutes) are not usually detectable in the effluent.

Atmospheric emissions of iodine-123, fluorine-18, thallium-201 and gallium-67 from the NMC are regulated by ARPANSA under the ANSTO Airborne Radioactivity Discharge Authorisation. The liquid waste discharges from the NMC to the sewer are covered by a trade wastewater agreement with Sydney Water Corporation that incorporates limits set by the New South Wales Department of Environment and Conservation (DEC, formerly the NSW Environment Protection Authority, EPA) for specific radionuclides in the discharges.

2.4 LIQUID EFFLUENT TREATMENT

Liquid effluent from the LHSTC is analysed and discharged via ANSTO's Main Discharge Pipeline (MDP, indicated on **Figure 2**, see section 5) to the Sydney Water Corporation sewer. The MDP is regularly inspected and maintained by ANSTO personnel. The effluent contains low levels of radionuclides, mainly tritium, and also cobalt-60, chromium-51, caesium-137, iodine-131, radium-226, and occasionally cerium-144 and caesium-134.

The annual volume of effluent discharged is typically 80,000 to 100,000 m^3/year; comprising approximately 50% sewage, 45% non-active trade waste effluent and 5% low-level active wastewater from laboratories where radioactive materials are routinely handled. The low-level active effluent undergoes an alum-based chemical treatment process for the removal of radionuclides. The trade wastewater is tested and chemically treated if necessary. Sewage is partially treated by aeration on-site. The three liquid waste streams are combined in holding tanks and tested for radioactive content and specified non-radiological water-quality parameters prior to discharge to the sewer. Sewage from the Sutherland Shire, including ANSTO's effluent, is tertiary-treated at the Cronulla Sewage Treatment Plant (STP) before being released to the sea at the Potter Point ocean outfall (shown on **Figure 1**, inset, see section 5).

2.5 LITTLE FOREST BURIAL GROUND

Between 1960 and 1968, the Australian Atomic Energy Commission (AAEC, the precursor to ANSTO) used a small area locally known as Little Forest (**Figure 1**, see section 5) for the disposal, by burial, of solid waste with low levels of radioactivity and of beryllium oxide (non-radioactive) that was generated predominantly at the LHSTC. Routine maintenance of the LFBG includes regularly mowing the grass and filling any shallow depressions in the trench area with clay/shale of local origin. Regular surveillance and monitoring of the LFBG is designed to detect any off-site transport of radionuclides by windborne transport of soil particles or in surface waters or groundwater.

3. Regulatory and Legal Framework

The Australian Nuclear Science and Technology Organisation (ANSTO) was formed in 1987 and is a Commonwealth Government Statutory Authority. It superseded the AAEC, which originated in 1953. In accordance with Section 7A of the *Australian Nuclear Science and Technology Organisation Act* 1987, ANSTO is exempt from the application of State laws where those laws relate to the use of land, environmental consequences of the activities of ANSTO, radioactive materials and dangerous goods, or certain types of licensing. Notwithstanding this, ANSTO has a policy of satisfying relevant NSW statutory requirements, where no Commonwealth legislation exists. Key legislative and regulatory requirements at ANSTO facilities in relation to environmental protection are summarised in **Table A**.

ANSTO reports to ARPANSA under an Airborne Radioactive Discharge Authorisation that incorporates a multi-layer system of radiological protection, designed to ensure that doses to the public are kept As Low As Reasonably Achievable (the ALARA principle). For practical implementation of the ALARA objective, the airborne discharge authorisation incorporates a system of conservative notification levels for stack discharges. Further explanation of notification

Table A. Key legislative and regulatory requirements relevant to ANSTO facilities in relation to environmental protection.

Driver	Organisation	Summary
Australian Radiation Protection and Nuclear Safety Act 1998 and *Regulations* (1999)	ARPANSA	Licences and regulates the operation of Controlled Facilities and the production, use and disposal of radioactive materials at all ANSTO sites; specifies exemption levels.
Airborne Radioactive Discharge Authorisation (ARPANSA 2001)	ARPANSA	Reports against facility licence conditions. Incorporates a multi-layer system of radiological protection, designed to ensure that doses to the public are kept as low as reasonably achievable (ALARA) for the LHSTC and NMC.
Trade Wastewater Agreement (No. 4423, 2003/2004; ANSTO and Sydney Water Corporation 2003)	Sydney Water Corporation	Authorisation to discharge treated liquid effluent from LHSTC to the sewer.
Trade Wastewater Agreement (No. 13966, 2001/2002; ANSTO and Sydney Water Corporation 2002)	Sydney Water Corporation	Authorisation to discharge treated liquid effluent from the NMC to the sewer.
Protection of the Environment Operations Act 1997 (NSW)	NSW DEC (formerly NSW EPA)	The *Clean Waters Regulations* 1972 Provides radiological limits for Class C stormwater/surface water drainage.
Crown Lands Act 1989 (NSW)	NSW Government	Environmental protection principles are observed in relation to the management and administration of ANSTO sites.
Environment Protection and Biodiversity Conservation Act 1999	Commonwealth Government	Environmental assessment of projects having national importance (*eg.* RRR).
National Biodiversity Strategy (1996)	Commonwealth Government	Integration of biodiversity conservation with natural resource management.
Native Vegetation Act 2003 (NSW)	NSW Government	Conservation and management of native vegetation.
Rural Fires Act 1997 (NSW)	NSW Government	Bushfire hazard management.

levels is given in Hoffmann *et al.* (2001). The ALARA objective is 0.02 mSv/year, which is 2% of the 1 mSv/year limit for annual effective dose to members of the public that is recommended by ARPANSA (ARPANSA 2002a).

Routine discharges of treated, low-level liquid effluent from the LHSTC and NMC are made to the sewer under the terms of trade wastewater agreements negotiated with Sydney Water Corporation (ANSTO and Sydney Water Corporation 2002, 2003), and discharges are independently checked for compliance by Sydney Water Corporation and ARPANSA. Liquid effluent discharges from the LHSTC are required to comply with (a) drinking water quality levels for radioactivity at the Cronulla STP, and (b) concentration limits for non-radiological components of the effluent. For compliance measurements of activity concentrations at the LHSTC discharge point, an agreed dilution factor of 25 is assumed. This factor was previously determined by tracer studies (Hoffmann *et al.* 1995, 1996), and is checked every year.

Prior to each discharge, the LHSTC effluent is checked for compliance with the acceptance limits for gross (or 'unspecified') alpha and beta activity, and tritium. The unspecified alpha- or beta-emitting radionuclides are considered to be present as the most restrictive isotopes for each decay type, *ie* radium-226 (alpha decay) and strontium-90 (beta decay). Compliance with the requirements of the trade wastewater agreement is demonstrated by determining the concentration quotient for the flow proportional pipeline composite samples which are taken every four discharge days. This quotient is the sum of the concentration of gross alpha, gross beta and tritium radioactivity divided by the permitted concentration for radium-226, strontium-90 and tritium respectively, and must not exceed one. Similarly, liquid effluent discharges from the NMC are also subject to limits set for specific radionuclides stipulated in the trade wastewater agreement with Sydney Water Corporation (ANSTO and Sydney Water Corporation, 2002).

Stormwater from the LHSTC flows into small local streams that are classified as Class C surface waters under regulations associated with the *Protection of the Environment Operations Act* 1997

(NSW). The regulations set out relevant limits for gross alpha and beta radioactivity in these waters. The Australian Drinking Water Guidelines (ADWG; NHMRC and ARMCANZ 2001) are used to provide context for the presence of tritium and some other radionuclides in surface waters and groundwater, although there are no legal or other requirements for ANSTO to meet these levels and the guidelines themselves state that they are not applicable to environmental releases of radionuclides under regulatory control. Following their endorsement in 1996, the ADWG have been subject to an ongoing revision process that ensures the guidelines represent the latest scientific evidence in relation to good quality drinking water. In 1996 the ADWG gave a specific concentration guideline for tritium (7600 Bq/L) but in subsequent revisions a single guideline dose (1 mSv/year) for annual exposure to radioactivity in drinking water has been given. Dose estimation, based on the method given in the ADWG, indicates that a person drinking water with a tritium concentration of 7600 Bq/L would receive an estimated dose of 0.1 mSv over a year (*ie* a contribution from tritium of 10% of the current guideline level). In referring to the ADWG guidelines for tritium, 7600 Bq/L is assumed to be an appropriate contextual level in this report.

4. Assessment of Potential Exposure

4.1 BACKGROUND RADIATION

Background radiation is naturally present in our environment. The average natural background effective dose-rate to the Australian public of ~1.5 mSv/year; (Webb *et al*. 1999) consists of ~0.9 mSv/year from external radiation sources (such as terrestrial and cosmic radiation) and ~0.6 mSv/year from internal radiation sources (such as potassium-40 and radon). Natural background radiation varies from place to place on the earth (*eg* with rock type and altitude) and is affected by lifestyle (*eg* choice of building materials, ventilation of homes, frequency of flying). The radiation dose from natural background averaged worldwide is estimated at ~3.5 mSv/year, but can be greater than 50 mSv/year (ARPANSA 2002b).

In October 2002, ARPANSA conducted a baseline gamma survey of the natural radiation in the suburbs within a 5km radius of the LHSTC (ARPANSA 2002b). The values measured ranged from close to the Australian average to about half of that value. The results for the Lucas Heights area reflect the predominance of sandstone, which has lower levels of uranium and thorium than most other rock types and produces less background gamma radiation.

4.2 EXPOSURE PATHWAYS AND CRITICAL GROUPS

Nuclear facilities contribute radioactivity that is additional to the background radiation we all experience and, consequently, such facilities are subject to very strict controls. In Australia, the recommended maximum additional public dose is 1 mSv/year (ARPANSA 2002a). ANSTO has a site dose constraint of 0.3 mSv/year (LHSTC) and a much lower ALARA objective of 0.02 mSv/year for dose to the public from airborne emissions from the LHSTC and NMC sites.

The concepts of *exposure pathways* (the possible avenues by which members of the public could be exposed to radioactivity originating from a given source) and *critical groups* (people at greatest potential risk of radiation exposure) are used internationally to derive discharge levels for release of radioactivity into the environment, and form the basis for ARPANSA regulations.

Potential exposure pathways by which radionuclides routinely discharged from ANSTO sites could lead to radiation exposure of members of the public, are:

- airborne emissions causing external radiation doses from dispersing radioactive gases;
- rain-out or deposition of airborne radionuclides entering the food chain, leading to exposure by drinking water or eating food;
- discharge of low levels of radioactivity through the Sydney Water Corporation sewage treatment system and into the sea, leading to exposure of workers at the sewage treatment plant, uptake by fish and accidental ingestion of seawater by swimmers; and
- contamination of groundwater or soil used for drinking or food production, leading to exposure by ingestion/inhalation.

Impact assessments for any activity associated with a nuclear facility are estimated as radiation doses to members of the public. A critical group is defined as a reasonably homogeneous group

of members of the public typical of individuals who are likely to receive the highest radiation dose via a given exposure pathway from a given source (IAEA 1996). The size of a critical group will usually be up to a few tens of persons but may consist of a single hypothetical individual (ICRP 1984). In order to satisfy the homogeneity criterion, the ratio of the maximum to minimum dose values should not exceed ten across the critical group.

In 2002, ANSTO identified theoretical critical groups for assessing the potential impact of its airborne and liquid effluent discharges from the LHSTC. Realistically assessed doses for the critical group of people potentially exposed to routine liquid effluent releases were at most a quarter of the dose estimated for the critical group potentially affected by routine airborne releases (Hoffmann *et al.* 2003).

5. Sampling of Emissions and Environment

The ANSTO routine monitoring program for the 2003-04 financial year is summarised in **Table B**. The table describes the media sampled, the range of analyses performed, and the location and frequency of sampling. A total of approximately 6,300 samples were taken and some 11,100 analyses performed. Detailed descriptions of sampling and analytical methods are given in Hoffmann *et al.* (2001).

5.1 AIR AND LIQUID EMISSIONS

Airborne radionuclide emissions are monitored at 16 stacks at the LHSTC and one at the NMC. Airborne emissions are passed through HEPA-filters to remove particles and charcoal filters to remove vapour, prior to discharge through stacks. The stacks were sampled continuously by drawing off a proportion of the airflow and accumulating weekly data for specific radionuclides from either real-time measurement or after physico-chemical trapping over a week. Tritiated water vapour was trapped from air bubbled through a series of water-filled bottles. Radio-iodine was sampled using charcoal-filled 'Maypack' cartridges, also fitted with particle filters. Noble gases were measured in-situ using a gamma detector and recording daily accumulations of counts. Airflow through each stack was measured on a quarterly basis using a hot-wire anemometer. Combined, these measurements enable reporting of total radionuclide releases from each stack.

Proportional samples of all liquid effluent discharges were collected and analysed for gross alpha and gross beta radioactivity, tritium, pH, biological oxygen demand, grease, suspended solids, total dissolved solids, ammonia and zinc. A volume-weighted composite sample was also produced from all pipeline samples each month and analysed for polonium-210 and gamma radioactivity.

5.2 ENVIRONMENT

Environmental sampling is carried out primarily to determine where and in what quantities radioactive emissions from the LHSTC are found in the local environment. ANSTO's environmental sampling strategy is based on our knowledge of potential radionuclide emission sources and the environmental pathways that may result in a potential dose to the public. Samples of various media, including surface waters and groundwater, air and soil, plus some biota, are collected at locations in and around the LHSTC. These sample sites are shown in **Figures 1** to **4**. Sampling locations include local creeks (*eg* Mill, Bardens and Forbes Creeks), the Woronora River, the LFBG and Potter Point. Testing of environmental samples for radioactivity includes tritium analysis of water samples, gross alpha and gross beta analysis of water and sediment samples, and gamma spectrometric measurements of various media.

Water sampling formed the greater part of the environmental sampling program in the period from July 2003 to June 2004. The stormwater bunds at the LHSTC (A, B and C in **Figure 2**) were sampled on working days, prior to the bunds being emptied. These daily samples were combined to give representative monthly samples of stormwater. Weekly samples were taken at Bund C, on the MDP creek that drains ANSTO's waste operations area, and at a natural pool some 60 metres further downstream (**Figure 2**). Weekly samples were also collected at the Bardens Creek weir, downstream of the stormwater Bund A. For some analyses, weekly samples were combined into monthly composites. Monthly water samples were taken from the State

Table B. SUMMARY OF ENVIRONMENTAL MONITORING AT ANSTO SITES, July 2003 to June 2004

SAMPLE	TYPES	ANALYSES	LOCATIONS	SAMPLING FREQUENCY	ESTIMATED SAMPLES	ESTIMATED ANALYSES
				per year	per year	per year
SOURCE MONITORING						
Airborne	Gases & particles (Maypacks)	GA, GB, Gamma	15 Stacks (LHSTC); 1 Stack (NMC)	Daily (work; NMC) and Weekly(LHSTC)	2050	5170
	Air flow	Flow	15 Stacks (LHSTC)	Weekly(Maypacks) and Quarterly(Stack)	840	840
	Gases	Gamma	3 Stacks (LHSTC); 1 Stack (NMC)	Daily(work)	980	980
	Gas (water vapour)	HTO	4 Stacks (LHSTC)	Weekly	208	208
Liquid	Wastewater	HTO, GA, GB	1-2 Holding Tanks (LHSTC Waste Optns)	Daily(work)	368	1104
	Wastewater	HTO, GA, GB, Chem	1 Sample Tank (LHSTC Waste Optns)	Every 3-4 Days	104	416
	Wastewater	HTO, GA, GB, Gamma	1 Sample Tank (LHSTC Waste Optns)	Monthly(from pipeline composites)	12	48
ENVIRONMENTAL MONITORING						
Waters	Rainfall	volume	1 Site (LHSTC)	15 minute intervals		
	Stormwater	HTO	3 Bunds (A, B, C)	Daily(work) to give Monthly composite	735	36
	Stormwater	HTO, GA, GB, Gamma	1 Bund (C); 1 Site (MDP+60m)	Weekly and Monthly composite (from weekly samples)	128	512
	Creek or river or estuary	HTO	3 Sites (Barden's Ck, Forbes Ck, Woronora R)	Weekly(B Ck) and Monthly(F Ck, W R)	76	76
	Creek or river or estuary	GA, GB	5 Sites (B Ck, MDP Ck, Strassman Ck, B&Mill Cks jnctn)	Monthly(B, M & S Cks) and Yearly(B&M Cks jnctn)	38	74
	Creek or river or estuary	Gamma	2 Sites (B&Mill Cks jnctn)	Yearly	2	1
	Seawater	HTO	1 Site (Potter Pt; ~20 samples)	6 Monthly (ie twice per year)	40	40
	Wastewater	HTO	3 Sewage Treatment Plant (Cronulla)	Yearly	263	263
	Groundwater	HTO, GA, GB, Gamma, WQ	19 Bores (LFBG)	6 Monthly	38	342
	Groundwater	HTO, GA, GB, Gamma, Chem	27 Bores (LHSTC & Buffer Zone)	Yearly	27	135
	Groundwater	WQ	27 Bores (LHSTC & Buffer Zone)	Quarterly	108	540
	Sump water	HTO, Gamma	1 Sump (B27)	Monthly	12	24
Air	Wind	speed & direction	1 Site (LHSTC at 10 and 49m)	15 minute intervals		
	Air	temperature, humidity	1 Site (LHSTC at 2, 10 and 49m)	15 minute intervals		
	Gases (Maypacks)	Gamma	4 Stations (LHSTC)	Weekly	208	208
	Particles	Pu, Be	1 Site (LFBG)	Quarterly Be and Pu	3	6
Soil/Sediment	Sediment	GA, GB, Gamma	3 Bunds (A, B, C); 2 Cks (Bardens, Mill Ck)	Yearly	5	15
Biota	Algae & fish & barnacles	Gamma	2 Sites (Potter Pt, RNP)	6 Monthly	12	12
Dosimetry		Rate survey	2 Sites (Effluent Pipeline, LFBG)	6 Monthly(E-pipe) and Yearly(LFBG)	3	3
		TLD	19 Sites (LHSTC, Suburbs, Cronulla STP)	Quarterly	76	76
INVESTIGATIONS						
Soil/Sediment	Soil/Sediment	Gamma	2 Areas (LFBG, Effluent Pipeline)	As indicated by dose-rate survey		
				APPROXIMATE TOTALS	6336	11129

Notes: 1. Working days assumed to be 245, excluding weekends and public holidays.
2. HTO = tritium analysis (after distillation).
3. GA = Gross Alpha counting; GB = Gross Beta counting.
4. Gamma = Gamma spectrometry that varies in number of nuclides targetted (can include specific noble gases like Ar-41 or individual radionuclides like I-131).
5. Chem = non-radiological analysis that varies in number of analytes (can include major ions, selected metals, organics, plant nutrients, pH, conductivity, suspended solids).
6. Water Quality (WQ) = field WQ parameters (e.g. water level, pH, conductivity).
7. Flow through Maypacks is measured using a floating ball gauge, and in stacks using a hot-wire anemometer.

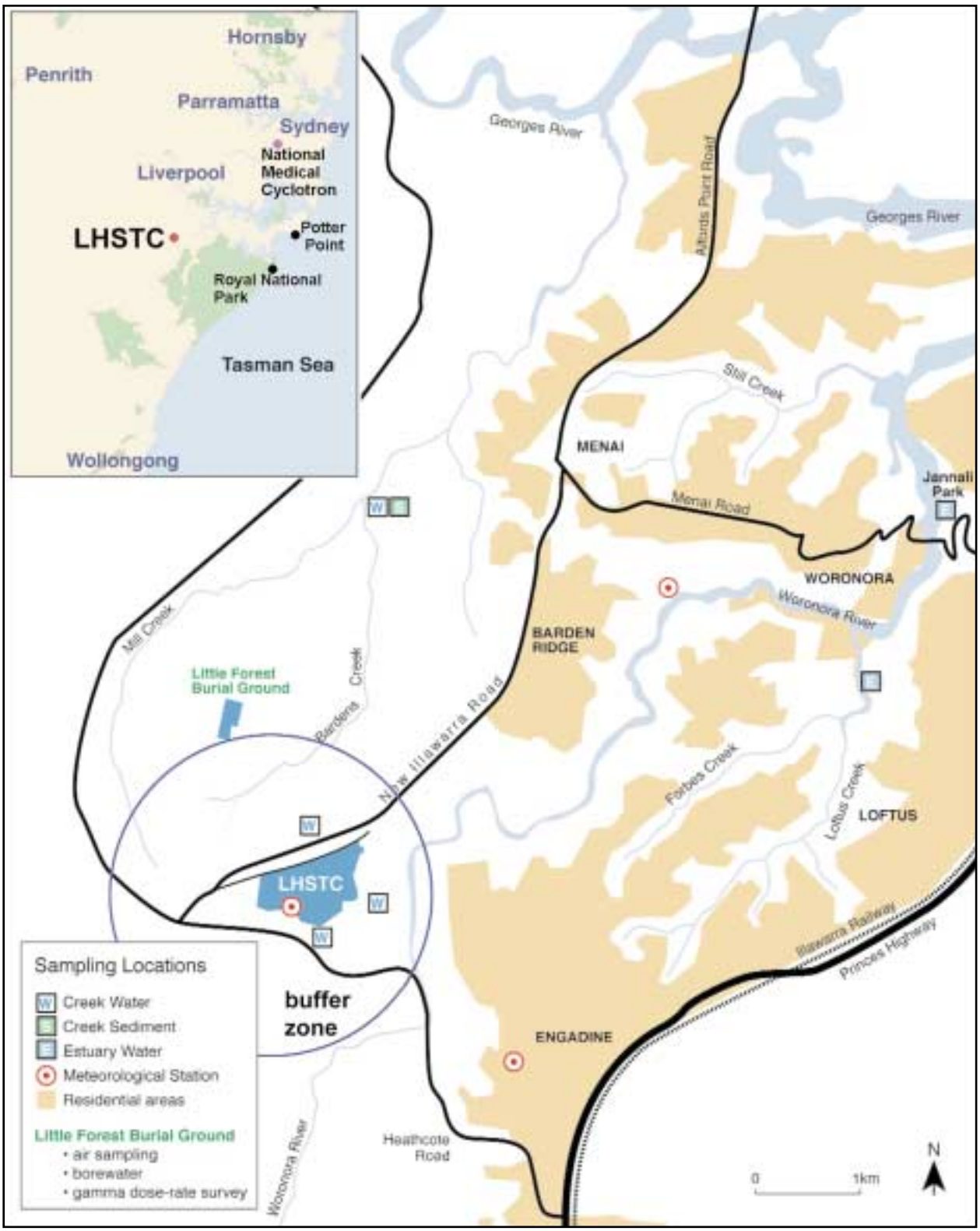

Figure 1. Location of ANSTO sites (the Lucas Heights Science and Technology Centre and the National Medical Cyclotron) and off-site monitoring points.

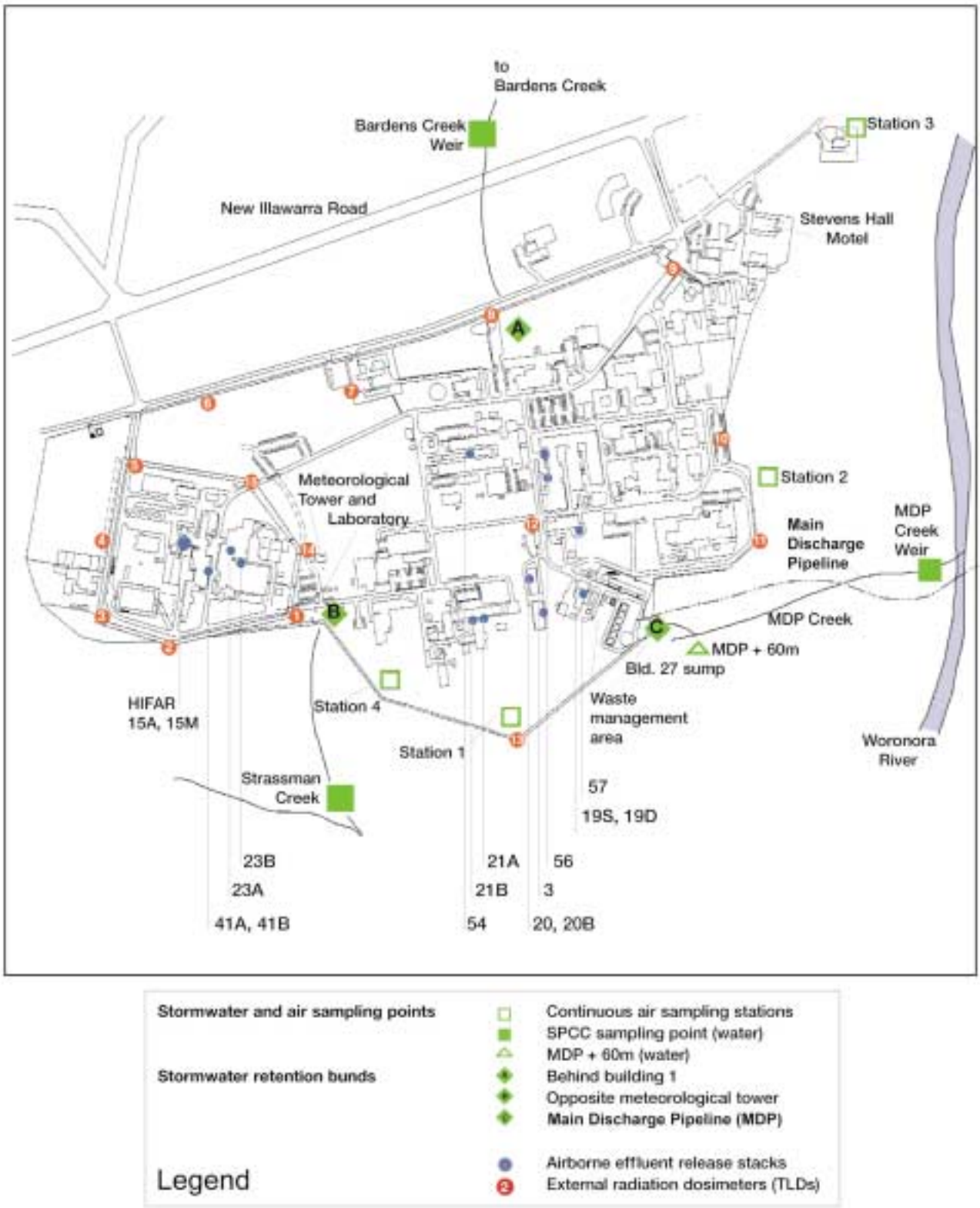

Figure 2. Location of stormwater, air and external radiation monitoring points at the LHSTC.

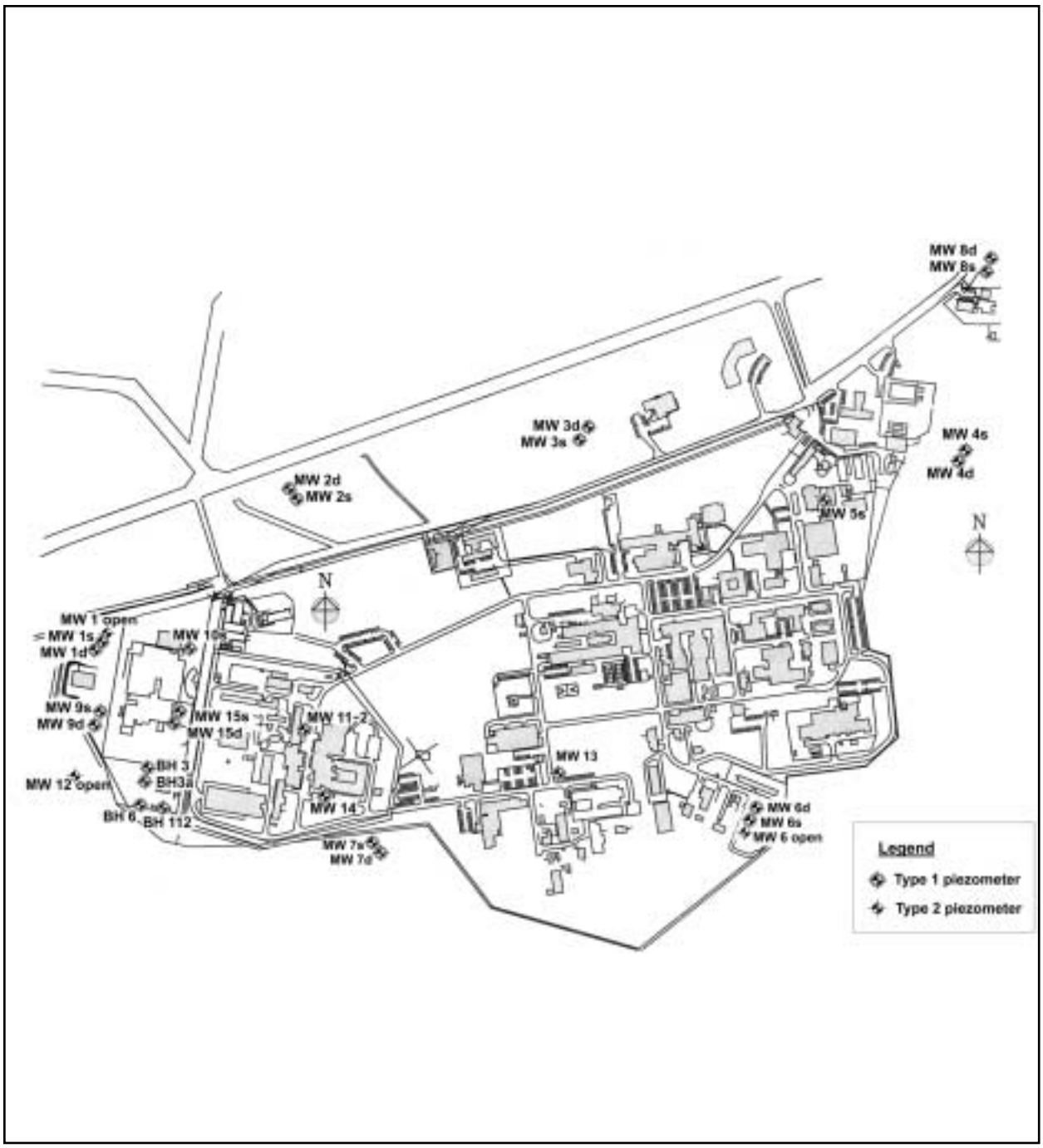

Figure 3. Location of groundwater monitoring piezometers at the LHSTC.

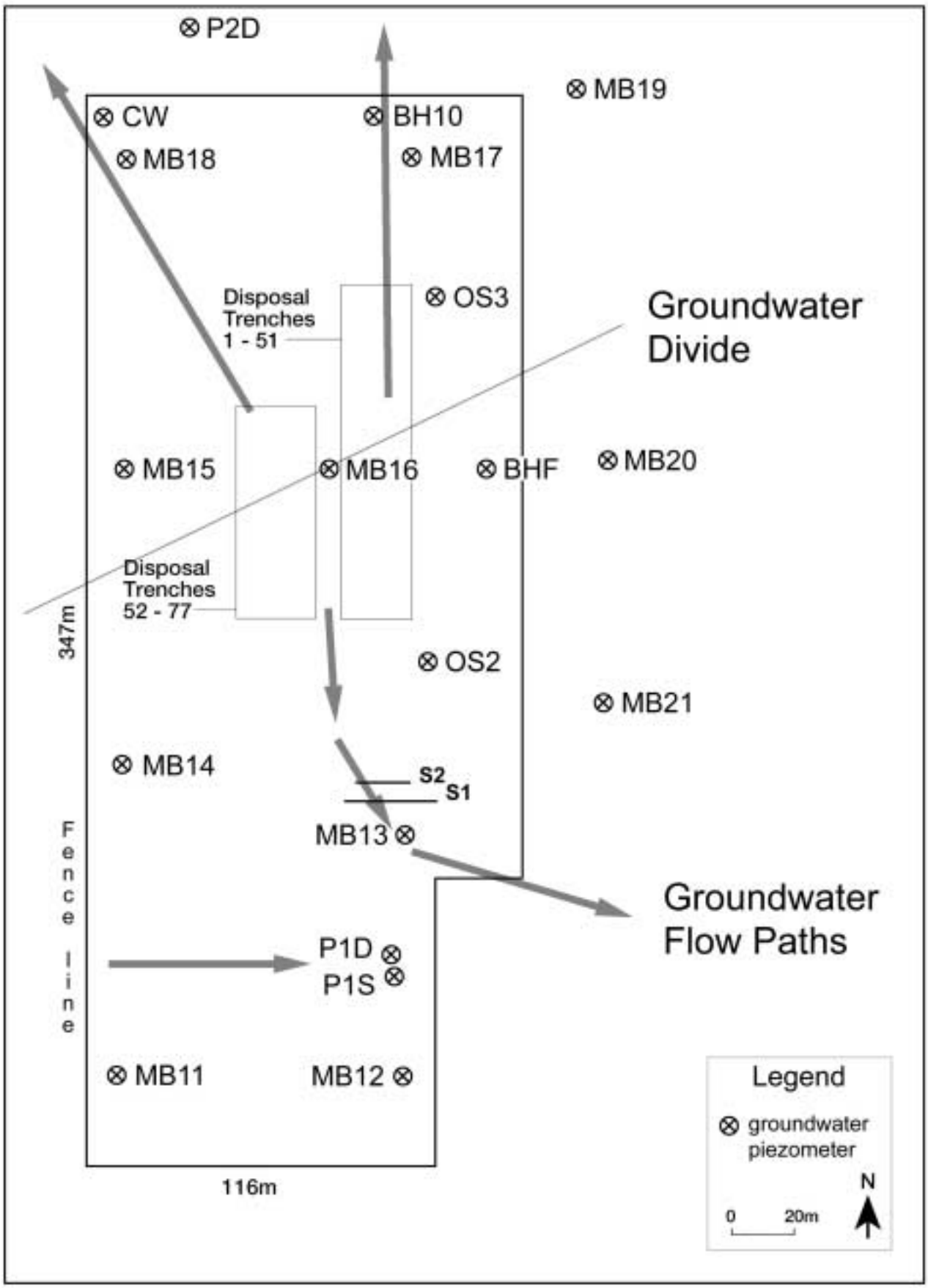

Figure 4. Little Forest Burial Ground – schematic showing the waste trenches, groundwater flow paths and piezometers currently monitored.

Pollution Control Commission (SPCC) sampling points (named for having been selected by the then SPCC in 1975; see **Figure 2**) at Bardens Creek weir, Strassman Creek and MDP Creek. These sites lie on the drainage lines leaving the LHSTC but are within ANSTO's 1.6 km buffer zone. Sampling also occurs in the local area beyond the buffer zone, with monthly samples of estuarine water collected from Forbes Creek and the Woronora River. Water and sediment samples were collected annually from near the junction of Mill and Bardens Creek, which drain the LFBG.

Groundwater monitoring at the LHSTC was first reported for 28 piezometers in Hoffmann *et al.* (2003). The LHSTC groundwater monitoring network now has 27 Type 1 piezometers (characterised as either shallow or deep) and three Type 2 (open) piezometers, following some changes that were necessary to accommodate RRR construction activities. This network has been designed to monitor specific facilities and to sample representative groundwater flows within and adjacent to the LHSTC (**Figure 3**). Groundwater from the nested (shallow and deep) Type 1 piezometers was purged and sampled approximately every three months in 2003-04. Piezometer MW11-2 replaces MW11, which became unusable due to a misaligned casing. Groundwater was sampled at the LFBG every six months.

Levels of gamma radiation over the burial area at the LFBG are surveyed annually to monitor surface soil dose-rates. The Main Discharge Pipeline (**Figure 2**) is surveyed annually for dose-rates along the accessible sections in order to detect any leaks.

Airborne particles were collected at the LFBG using a high-volume sampler approximately every two weeks for the species of interest: plutonium-239/240 and beryllium. Ambient air is sampled continuously using Maypacks and particle filters at four locations on the LHSTC boundary fence.

5.3 METEOROLOGY

In common with similar organisations operating nuclear facilities, ANSTO undertakes a program of meteorological measurements. The prime reason for such a program is to allow estimates to be made of the downwind concentration of any airborne pollutants, particularly radionuclides, released from the LHSTC through routine operations or under accident conditions.

The on-site meteorological tower and associated laboratory are shown in **Figure 2**. Two off-site meteorological stations are also used to measure the influence of the local terrain on wind flow, dispersion patterns and temperatures. These stations (**Figure 1**) are located at the Boys' Town School (Engadine) and at the 'Shackels Estate' in the Woronora River valley. The meteorology program includes measurements of wind speed, direction and variability, as well as precipitation, evaporation, temperature, pressure and humidity. These data are collected and analysed continuously, and are displayed on ANSTO's web site in addition to being reported to the Australian Bureau of Meteorology. The long-term climatology data for the LHSTC from 1991 to 2003 was recently published (Clark 2003).

6. Environmental Monitoring (July 2003 - June 2004)

Monitoring data in this report cover the financial year from July 2003 to June 2004 and are presented in **Tables 2** to **39**. Measurement uncertainties given in these tables are at the two-sigma level *(ie* twice the standard deviation), unless otherwise noted. For some environmental samples, analytical results were not significantly different from background levels and are reported as being below the Minimum Detectable Activity (MDA), calculated with 95% confidence.

The MDA can differ between sample types and radionuclides. Indicative median MDAs for various radionuclides and environmental media are given in **Table 1** (see Data Tables section below). In general, data are summarised as median ± interquartile range (IQR), where the IQR is the 75th minus the 25th percentile of the data, a similar concept to a standard deviation relative to the mean.

6.1 AIRBORNE EMISSIONS

Table 2 lists the airborne activity discharges for the 2003-04 financial year from the single stack at the NMC and 16 stacks at the LHSTC. The table shows the total amount of radioactivity discharged and the discharges expressed as a percentage of the relevant annual notification levels. The 'all other nuclides' column includes all radionuclides for which there is no specific notification level. Notification levels act as conservative triggers for follow-up investigation and are more fully explained in Hoffmann *et al.* 2001. Airborne monitoring of the stack for building 20B, the new waste treatment and packaging facility, commenced in June 2004. Stack 21B, which ventilated a single laboratory, was withdrawn from service in December 2003 following the cessation of all work with radioactive materials in the laboratory.

Emissions of airborne iodine-123 from the NMC reached 47.8% of the annual notification level, very similar to the levels of the past two financial years. All other nuclides reached only 6.9% of annual notification levels, continuing a downward trend over the past three financial years.

All gross alpha and gross beta radioactivity, associated with airborne particles sampled from LHSTC stacks, was less than 5% of annual notification levels. The airborne discharge of argon-41 from stacks 15A and 15M (HIFAR) remained below notification levels in the 2003-04 financial year, reaching 61.0% and 56.9% of their respective notification levels. The airborne discharge of tritium from 15A, which accounts for most of the airborne tritium emission at the LHSTC, reached 28.1% of the annual notification level, similar to the previous financial year and reflecting consistently low emissions. Iodine-131 emissions from stack 23A (ARI) reached only 17.0% of the annual notification level. Discharge of iodine-131 from stack 54 (ARI) increased over the previous year, reaching 74.6% of the annual notification level, primarily as a result of a single second quarter peak. The annual emission of iodine-131 remained within normal operational expectations. Noble gas emissions from stack 54 also increased in 2003-04, in association with the radioiodine peak mentioned above. Airborne emissions of xenon-133 reached 146.6% of the annual notification level, and the CEO of ARPANSA was notified. The underlying cause of the increased emissions from stack 54 was investigated and found to be related to the irradiation of uranium targets for the production of the molybdenum-99 used to manufacture the Gentech® generator which is used in over 70% of Australian nuclear medicine procedures. Temporary suspension of molybdenum production and exchange of a charcoal filter unit were among the initial precautionary responses by ANSTO.

6.2 LIQUID EFFLUENT

6.2.1 Lucas Heights Science and Technology Centre

The LHSTC effluent is routinely screened for tritium, gross alpha and gross beta activity as well as non-radiological water-quality parameters. Monthly, volume-weighted composite samples of all discharges are analysed for polonium-210 (a volatile alpha-emitter) and gamma-emitters, including caesium-137, caesium-134, cerium-144, chromium-51, cobalt-60, iodine-131, lead-210, radium-226 and radium-228.

The total volume discharged in the 2003-04 year was 73,972 m^3. **Table 3** shows the average monthly activities of gross alpha, gross beta and tritium radioactivity in liquid effluent prior to discharge. The alpha values are all less than the minimum detectable activity, the median of which was 100 Bq/m^3, hence the combined quotients in the last column are also shown as less-than values. The combined monthly activity quotients for alpha, beta and tritium activity ranged from < 0.03 to < 0.16, with a median value of < 0.07, *ie* less than 7% of the allowed quotient of one. **Figure 5** charts the monthly quotients for alpha, beta and tritium activities in liquid effluent discharges for the period July 2003 to June 2004.

The activities of gamma-emitting radionuclides in the monthly pipeline composite samples are given in **Table 4**. Of the radionuclides listed, only caesium-137 was detected in more than 50% of samples, ranging from less than the minimum detectable activity (0.21 Bq/L) to 6.06 Bq/L, with a median of 2.84 ± 1.88 Bq/L. Iodine-131, cobalt-60 and radium-226 were each detected in only 33% of monthly composite samples. The activity of cobalt-60 ranged from less than the minimum detectable activity (0.13 Bq/L) to 0.58 Bq/L. Alpha-spectrometry results for polonium-210 in the monthly composite samples were all < 0.01 Bq/L in 2003-04.

The results for non-radioactive parameters of the liquid effluent (suspended solids, pH, ammonia, biological oxygen demand, grease, zinc and total dissolved solids) are shown in **Table 5**, along

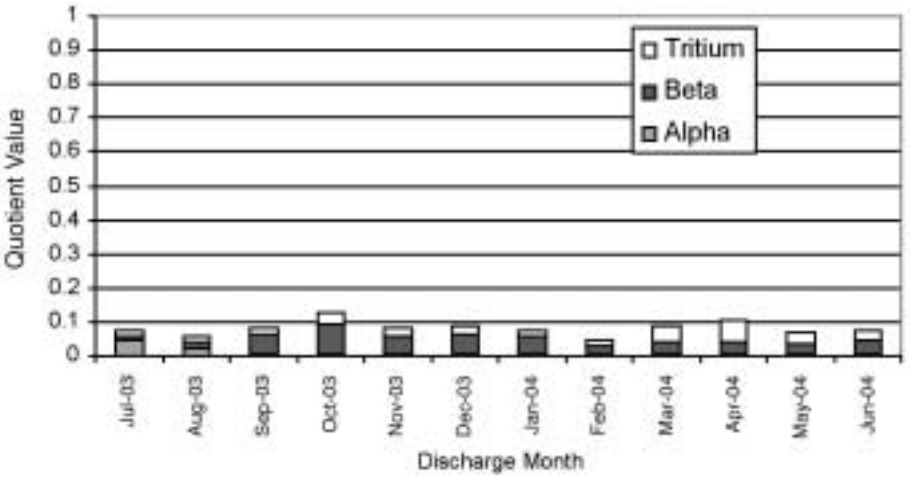

Figure 5. Monthly quotients for alpha, beta and tritium radioactivity in liquid effluent, LHSTC, July 2003 to June 2004.

with the relevant standards for acceptance to the Sydney Water Corporation sewer. The range of values is reported, along with the mean and median. Of the samples analysed, 95% must be less than or equal to the relevant standards for acceptance. For 2003-04, all median values were within acceptable bounds, although the range of pH indicates that occasional samples fell outside the standards.

Levels of radioactivity and non-radioactive components of all liquid effluent discharges to the sewer from July 2003 to June 2004 met the standards for acceptance specified in the trade wastewater agreement with Sydney Water Corporation.

6.2.2 National Medical Cyclotron

The average levels of radionuclides discharged to sewer each month from the NMC are shown in **Table 6**, along with calculated mean and median values. The average monthly discharge volume was 6 m^3, with a pH of 7.6. The discharges contained very low levels of activity, with median concentrations all less than 3% of the NSW DEC monthly limits for thallium-201, thallium-202, gallium-67, cobalt-57, zinc-65 and iodine-123. The highest monthly average concentrations of these isotopes were, respectively, around 9%, 32%, 3%, 2%, 2% and 13% of the levels specified in the trade wastewater agreement. Liquid effluent discharges from the NMC were therefore well within the required limits in the period from July 2003 to June 2004.

6.2.3 Effluent Dilution – LHSTC to the Cronulla STP

The Cronulla Sewage Treatment Plant (STP) receives sewage and wastewaters from the Sutherland Shire, including treated effluent from the LHSTC. ANSTO is required to comply with the Sydney Water Corporation trade wastewater agreement, which nominates a minimum value of 25 for the in-line dilution factor between the ANSTO discharge tanks and the Cronulla STP. The dilution factor is confirmed for at least two ANSTO effluent releases each year by direct measurement of tritium levels in the plant. The Cronulla STP was upgraded to provide tertiary treatment from July 2001. This upgrade has significantly increased the residence time of effluent within the plant. Under normal flow conditions, this causes an increase in the final effluent stream dilution and a reduction in the peak tritium concentration in the tertiary treated effluent.

To study the changes in residence time resulting from the STP upgrade, a seven day study was undertaken from 29 March to 5 April 2004, encompassing four separate effluent releases (**Table 7**). Samples were collected using automatic water samplers at three locations through the plant: (a) the inlet channel to the primary sedimentation tanks; (b) at the interstage following the primary sedimentation tanks and (c) after the tertiary filters prior to the final UV treatment. A total of 263 effluent samples were analysed for tritium.

The maximum tritium activities observed at the inlet, interstage and final effluent streams of the Cronulla STP during the study were 1302 Bq/L, 840 Bq/L and 194 Bq/L respectively. Prior to the tertiary upgrade, the interstage represented the final effluent stream leaving the Cronulla STP. The

minimum in-line dilution ratio at the interstage for the four releases was 42:1 (**Table 7**), which is somewhat above the median of ratios reported since 1994 (33:1) but well within previous experience. It would now be more appropriate to calculate dilutions at the new final effluent stream. However, the long residence time in the tertiary treatment stage between the interstage and the final effluent sampling locations resulted in an overlap in the tritium peaks from the four releases. Therefore the final effluent stream dilution can only be roughly estimated to be in the order of 200-300:1.

The March to April 2004 study utilised liquid effluent with above-average tritium concentrations. Despite this, the levels of tritium observed within the Cronulla STP during the study were significantly less than those stipulated in the Sydney Water Corporation trade wastewater agreement. This confirms that ANSTO fully complied with its obligations under the agreement. During the study, the mean tritium value in the final effluent stream was 77 ± 1 Bq/L, very low compared with the ADWG level of 7600 Bq/L.

The increased dilution of ANSTO effluent resulting from the Cronulla STP tertiary upgrade means that no distinct tritium peak occurs in the final effluent stream, and it is no longer possible to calculate an accurate transit time. Consequently the past practice of timing off-shore sampling to coincide with the tritium peak can no longer be achieved.

6.3 AIR

6.3.1 Ambient Iodine-131 in Air

Low concentrations of iodine-131 were detected in two of the weekly ambient air samples during 2003-04 (**Table 8**). The detection of these low levels in June 2004 is attributed to a combination of factors, including the prevailing winds and winter weather conditions as well as a slight increase in iodine-131 emissions. The remaining results were all below the minimum detectable level of 0.0025 Bq/m^3.

Results for ambient iodine-131 concentrations in air are conservative, since (a) any iodine-131 activity is corrected for decay from the first day of the sampling week, and (b) the four samples are analysed simultaneously, so any iodine-131 activity is assumed to have originated on one filter.

6.3.2 Little Forest Burial Ground – Airborne Particulates

Quarterly samples of airborne particles were collected at the LFBG on windy days (to maximise particulate collection) using a mobile high-volume air sampler. The total volume of air sampled during the year was 7464 m^3.

The exposed filters were analysed for beryllium via ICPMS and plutonium-239/240 by alpha spectrometry, and these results are given in **Table 9**. The mass of beryllium (measured in µg total on the filter portion) was converted to a concentration using the equivalent sampling volume. A trace of beryllium was reported (0.04 µg total or 6.8 x 10^{-5} µg/m^3). This very low value was below the median detection limit of 0.06 µg. The measured amount is well below the exposure standard for atmospheric contaminants such as beryllium in air of 2 µg/m^3 (Worksafe Australia: NOHSC 1995) applicable to workers exposed 8 hours per day, 50 weeks per year). No plutonium-239/240 was detected within the reporting period.

6.3.3 External Gamma Radiation

Thermoluminescent dosimeters (TLDs) were used to measure external gamma radiation (including the contribution from natural background radioactivity) at various locations around the LHSTC (**Figure 2**), at three private residences in the nearby suburbs of Barden Ridge, Engadine and Woronora and at the Cronulla STP. The data are given in **Table 10**. In 2002, dosimeters 3 and 5 were moved to their current locations due to the construction of the RRR. TLD number 17 was relocated from Engadine to Yarrawarrah in January 2004.

The TLDs at sites 2 and 3 on the southern sector of the LHSTC perimeter fence (see **Figure 2**) are affected by nearby stored radioactive material. This part of the site boundary is not readily accessed by the general public. The effective dose-rates from external gamma radiation for other locations at LHSTC were in the ranges 0.93 to 1.50 mSv/year for 2002-03 and 0.82 to 1.41

mSv/year for 2003-04. Measurements at the three local residences, which can be taken as indicative of local background for the LHSTC, showed external gamma dose-rates ranging from 0.98 to 1.24 and from 0.88 to 1.13 mSv/year for the 2002-03 and 2003-04 financial years, respectively, consistent with the background levels reported for Australian capital cities by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 2000). These ranges significantly overlap the ranges reported for TLDs at the LHSTC and show that ambient external radiation levels at the LHSTC are generally within the range of local background radiation.

Measurements of the external gamma dose-rates at the Cronulla STP were lower than at the LHSTC and the three local residences. This is attributed to the lower terrestrial radioactivity contribution as a consequence of the location of the TLD badge on a sewage holding tank approximately 2 m above ground level and the shielding effects of the sewage.

TLDs were also deployed outdoors at the NMC, and results for 2002-03 and 2003-04 are given in **Table 11**. The median external dose-rates for 2002-03 and 2003-04 were 1.83 ± 0.13 mSv/year and 1.66 ± 0.10 mSv/year, respectively. Whilst these values are higher than those at the LHSTC, these TLDs are mounted on walls and are therefore exposed to the additional natural radioactivity known to be present in brick or concrete (Kathren 1984). The LHSTC badges on the other hand, are predominantly situated in the open, away from buildings. The dose-rates at the NMC, which include background radiation, are very close to the average Australian natural background level.

6.3.4 Aerosol Particles

ANSTO has been measuring and characterising fine aerosol particles at Lucas Heights for the international Aerosol Sampling Program (ASP) for well over 10 years. The ASP is a study to determine the elemental composition of fine suspended particulates.

Fine aerosol particles with aerodynamic diameters less than 2.5 μm (referred to as PM 2.5) mainly originate from combustion sources such as motor vehicle exhausts, fossil fuel burning and high temperature industrial processes. ANSTO is not a significant source of such particulate emissions. Natural sources include bushfires, airborne soil particles and sea spray. **Figure 6** shows the average monthly mass of PM 2.5 particles collected at the LHSTC in the 2003 calendar year.

Although an Australian standard has not been set, the measured levels of fine particles in the calendar year 2003 were generally well within the requirements of the USEPA air quality standard which specify an annual average of 15 μg/m^3 (USEPA 2002). The peak values recorded in January 2003 were due to smoke from significant bushfires across NSW impacting the site. A more detailed analysis of the particulate composition demonstrated that most of the aerosol particles measured at the LHSTC did not originate from ANSTO activities. The summary data can be found on the ANSTO web-site (ANSTO 2004).

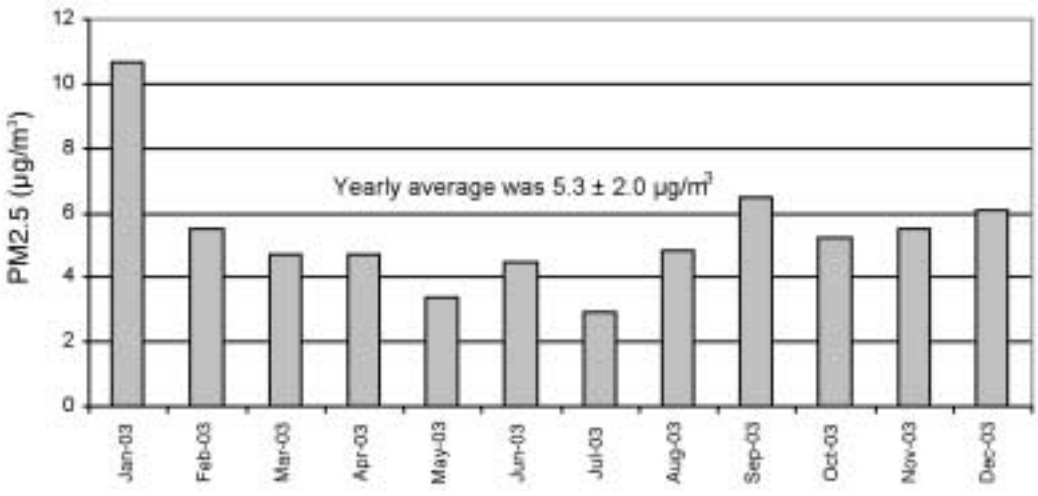

Figure 6. Average monthly mass of fine aerosol particles (less than 2.5 μm in diameter) collected over 24-hour periods at the LHSTC, January to December 2003.

6.4 SURFACE WATERS

Surface waters include stormwater runoff as well as discharges of near-surface groundwater, with the proportion depending on the weather in the preceding days. Concrete bunds (of about 6 m^3 capacity) on the three main stormwater outlets at the LHSTC (A, B and C in **Figure 2**) temporarily retain surface waters before their release off-site. These bunds are inspected and emptied each week-day morning to facilitate on-site containment and treatment of any small accidental releases of contaminated liquid. The bunds are also used as environmental monitoring points.

6.4.1 Tritium in Surface Waters

Tritiated water vapour released to air from HIFAR operations readily exchanges with rainwater and other surface waters and is present in stormwater and groundwater at the LHSTC. Tritium was detected in monthly composite water samples (work-daily samples combined) from Bunds A, B and C (**Table 12**) at levels ranging from 20 to 610 Bq/L, with a median activity of 70 ± 70 Bq/L.

Weekly samples from Bund C, situated at the top of MDP Creek, were analysed for tritium and the results are shown in **Table 13**. Tritium activity ranged from 10 to 450 Bq/L, with a median activity of 120 ± 90 Bq/L. Weekly samples were also collected from a natural pool on the same drainage line but some sixty metres downstream of Bund C – this was the stormwater sampling point prior to the construction of the bunds in 1994. The tritium levels in weekly samples from this site, MDP+60m, (**Table 14**) ranged from 30 to 300 Bq/L, with a median of 80 ± 80 Bq/L. Similarly, weekly water samples were collected from the Bardens Creek weir, downstream of Bund A on the north side of New Illawarra Rd (**Figure 2**). The results are given in **Table 15**. The tritium activity in weekly samples from Bardens Creek weir ranged from 10 to 350 Bq/L, with a median activity of 60 ± 40 Bq/L.

The range of tritium activities recorded in these water samples from July 2003 to June 2004 was typical of recent years at the LHSTC. The maximum tritium activity in any of the samples from stormwater bunds and nearby sampling points was less than 10% of the ADWG level of 7600 Bq/L (NHMRC and ARMCANZ 2001), given here for context only as this water is not collected and supplied as potable water. The median tritium activities for surface waters at LHSTC are much lower, in the range from 60 to 120 Bq/L, *ie* they are typically less than 2% of the ADWG levels.

6.4.2 Gross Alpha and Beta Radioactivity in Surface Waters

Stormwater from the LHSTC flows into three small streams (Bardens, Strassman and MDP Creeks; **Figure 2**), that are classified as Class C waters under the regulations associated with the *Protection of the Environment Operations Act* 1997 (NSW). As such, there are regulatory limits for gross (total) alpha and gross beta radioactivity of these waters (1.1 and 11.1 Bq/L, respectively) which apply at the SPCC compliance monitoring points.

Gross alpha and gross beta data for monthly composite samples (combined weekly samples) at Bund C are given in **Table 16** from July 2003 to June 2004. The alpha activities ranged from 0.01 to 0.24 Bq/L, with a median of 0.03 ± 0.02 Bq/L. For gross beta, the range of activities was from 0.12 to 4.42 Bq/L and the median was 0.26 ± 0.20 Bq/L. Gross alpha and beta data for monthly composite samples (combined weekly samples) downstream of the bund at MDP+60m are given in **Table 17**. The gross alpha activities ranged from less than the minimum detectable activity to 0.06 Bq/L, with a median of 0.03 ± 0.02 Bq/L. For gross beta, the range of activities was from 0.11 to 0.70 Bq/L and the median 0.22 ± 0.19 Bq/L. All of the measured alpha and beta levels comply with the regulatory limits for Class C surface waters. Although the regulatory limits were not exceeded, the Bund C results showed an increase in beta activity for April, May and, to a lesser extent, June. Analysis of the individual weekly water samples indicated that beta activity entered Bund C during the week of 6 to 13 April. The much lower concentrations seen in concurrent water samples taken 60 metres downstream indicate that the activity was essentially contained within the on-site bund. This was confirmed by analysis of sediments within, and downstream of, the bund. Once the anomaly was identified in mid-May, the Bund C sediments were removed and the bund was cleaned, hence the June composite was less affected. Note that residual amounts of particle-associated activity could persist in these areas for a time and may be included in the unfiltered water samples.

The results of gross alpha and gross beta analyses of monthly samples from Bardens Creek weir, Strassman Creek and MDP Creek weir are given in **Table 18**. An extra set of samples was

collected in response to the Bund C anomaly. Taking the three creeks together, gross alpha levels ranged from less than the minimum detectable activity to 0.03 Bq/L, with a median value of 0.01± 0.01 Bq/L. Gross beta radioactivity ranged from 0.01 to 0.22 Bq/L, with a median of 0.04 ± 0.10 Bq/L. Water samples collected near the junction of Mill and Bardens Creeks, which drain the LFBG, showed only natural background levels of gross alpha, gross beta, gamma and tritium activity (**Table 19**).

Figures 7 and **8** chart the 2003-04 gross alpha and beta activities for the monthly water samples from MDP Bund C, from downstream at MDP+60m and from the compliance monitoring point, MDP Creek weir. The data show the decrease in beta activity in Bund C following the removal of contaminated sediments, and that the anomaly had a minimal impact on the off-site monitoring points.

All results for surface waters from July 2003 to June 2004 were below the limits for gross alpha and gross beta activity in the relevant NSW regulations. In fact, 100% of alpha and 93.5% of beta results were below the ADWG screening level of 0.5 Bq/L.

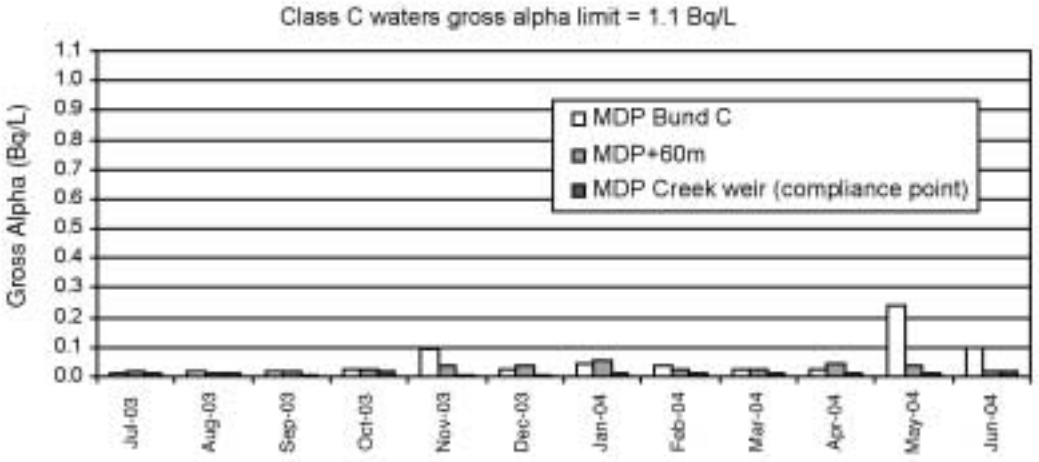

Figure 7. Gross alpha activity in monthly samples of surface waters from Bund C and MDP+60m (composites of weekly samples) and MDP Creek weir, July 2003 to June 2004.

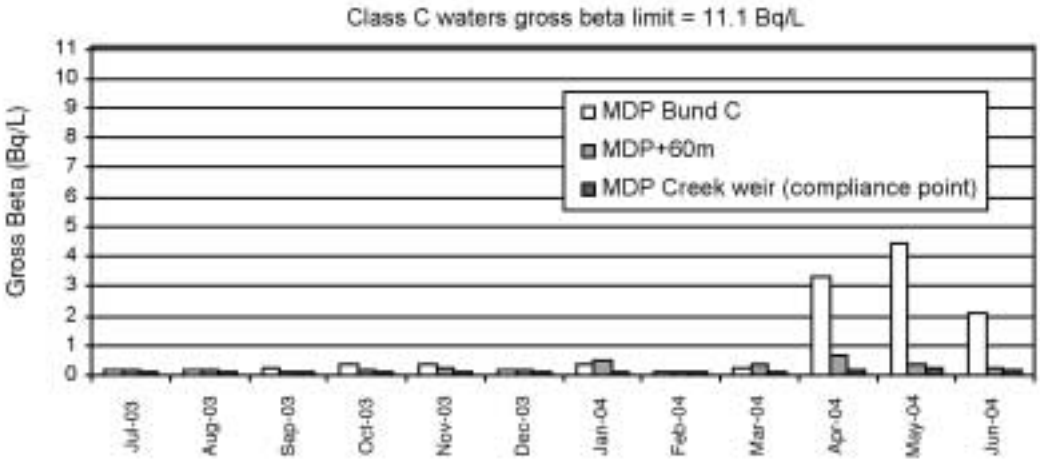

Figure 8. Gross beta activity in monthly samples of surface waters from Bund C and MDP+60m (composites of weekly samples) and MDP Creek weir, July 2003 to June 2004.

6.4.3 Gamma-emitting Radionuclides in Surface Waters

Gamma spectrometry results for monthly composite samples from Bund C are given in **Table 16**. Results for July 2003 to March 2004 generally showed typical, low levels of caesium-137, ranging

from less than the minimum detectable activity to 0.028 Bq/L, with a yearly median of 0.020 ± 0.069 Bq/L. Other gamma-emitters detected included potassium-40 and beryllium-7, both of natural origin. Beryllium-7 is a cosmic spallation product that undergoes dry and/or wet deposition processes. Consequently, it is often found in pooled surface waters. Similarly, isotopes from the LHSTC airborne discharges may occasionally be found, as was the case for iodine-131, which was measured twice in Bund C during the year. Results for April, May and June 2004 reflected the anomaly reported in section 6.4.2, with enhanced levels of caesium-137 plus cerium-144, cobalt-60, cobalt-57, ruthenium-103, ruthenium-106, zirconium-95 and niobium-95.

In monthly composite samples from the natural pool located approximately sixty metres downstream of Bund C (MDP+60 m, **Table 17**) caesium-137 was detected with a median activity of 0.013 ± 0.019 Bq/L. Similarly low levels of caesium-137 have been reported in previous years. Low levels of naturally occurring potassium-40 and beryllium-7 were occasionally detected. Whilst ruthenium-103 and ruthenium-106 were detected in the April composite sample, no extraneous activity was found in the following two months.

6.5 ESTUARINE AND SEA WATERS

Monthly samples of brackish/estuarine waters were collected from Forbes Creek (a tributary of the Woronora River) and the Woronora River and analysed for tritium. However, as in previous years, no significant activity was detected (all were < 10 Bq/L, apart from one value of 20 ±10 Bq/L). The results are presented in **Table 20**.

Seawater samples were collected in the vicinity of the Potter Point ocean outfall on two occasions; April 1 and June 22, 2004 (see **Table 7**). On each occasion, samples were collected at three locations at a depth of 1 metre below the surface. A total of 39 samples were collected, distilled and analysed for tritium in ANSTO's low-background facility. Of these, 31 samples were below the minimum detectable activity of 5 Bq/L. The first sampling occasion was timed to coincide with the Cronulla STP effluent study; during the off-shore sampling period the average tritium concentration in the final effluent stream was 44 Bq/L corresponding to a minimum off-shore dilution ratio of 11:1. These data indicate the further dilution that occurs between the Cronulla STP and the near-shore area at Potter Point.

6.6 GROUNDWATER

6.6.1 Lucas Heights Science and Technology Centre

The subsurface structure that conditions groundwater flow at the LHSTC can be conceptualised as three layers, comprising a near-surface soil and regolith layer, typically less than two metres deep, underlain by a weathered sandstone layer extending to approximately ten metres, with unweathered sandstone beneath that. Seismic, geophysical and hydrographic data show an imperfect multi-layer groundwater flow regime exhibiting a decrease in flow rate through each layer due to decreasing hydraulic conductivities with depth. Groundwater flow at the LHSTC is primarily dependent on topographic features. More than half of the area within the LHSTC fence is covered by grass or sparse native vegetation and it is the soil beneath this unpaved area that can absorb rainfall. Following heavy rain, water seeps from the soil into the heads of the gullies surrounding the LHSTC via a shallow groundwater path, with flow from the plateau to the gully typically peaking a few days after the rainfall event. Discharge also occurs through a deeper groundwater path, over a much longer time scale and further down the gullies. The potentiometric surface for this deeper sandstone aquifer is shown in **Figure 9**.

Groundwater seepage from the general vicinity of the intermediate-level waste storage facility (Building 27) is routinely collected. The samples were measured each month for gamma-emitting isotopes (americium-241, caesium-137, cobalt-60 and potassium-40) and tritium (**Table 21**). The sample collection for April was delayed until 12 May, in response to access problems. The sump was used for operational purposes from late May, hence further sampling was suspended. Gamma-emitting isotopes were not detected, and tritium activities were stable and well below ADWG levels, with a median of 480 ± 60 Bq/L.

The quarterly data for field parameters in groundwater and annual measurement of major ions are presented in **Tables 22-26**. Groundwater quality at the LHSTC is typical of a sandstone aquifer, tending to be acidic and with generally low salinity (indicated by electrical conductivity, EC). In

2003-04, pH measurements ranged from 3.6 to 8.2, with a median of 4.9 ± 0.9, and EC ranged between 138 and 1028 µS/cm with a median of 298 ± 126 µS/cm. The Eh, which indicates oxidation-reduction potential, was generally positive with a median of 220 ± 140 mV as would be expected of oxygenated waters. Some piezometers were found to have low or negative Eh, which is often associated with low oxygen concentrations. The generally turbid conditions reported for most piezometers probably relate to stirring of sediment during sampling (**Tables 22** to **25**). The LHSTC groundwaters are predominantly sodium-chloride-sulfate type waters, consistent with a primary influence from marine aerosol input (**Table 26**). Groundwater samples were collected at the LHSTC in August 2003, filtered and analysed for alpha, beta, tritium and gamma radioactivity, and the data are given in **Table 27**. Gross alpha activity ranged from 0.01 to 0.22 Bq/L, with a median of 0.05 ± 0.05 Bq/L. Gross beta activities were similar, ranging from 0.01 to 0.20 Bq/L, with a median of 0.05 ± 0.06 Bq/L. The gross alpha and gross beta activities in the groundwater were below the levels prescribed for Class C surface waters in New South Wales, but note that this comparison is indicative only because these are groundwaters. Gamma-emitting radionuclides, specifically americium-241, caesium-137 and cobalt-60, were not detected in 2003-04.

Tritium activity in the LHSTC groundwater (**Table 27**) ranged from 2.1 to 124.2 Bq/L, with a median of 12.6 ± 33.7 Bq/L (analysed by ANSTO's low-background tritium facility for enhanced sensitivity). The maximum activity measured in groundwater in 2003-04 was less than 2% of the ADWG (NHMRC and ARMCANZ 2001). Shallower piezometers generally displayed higher tritium levels than the deeper ones.

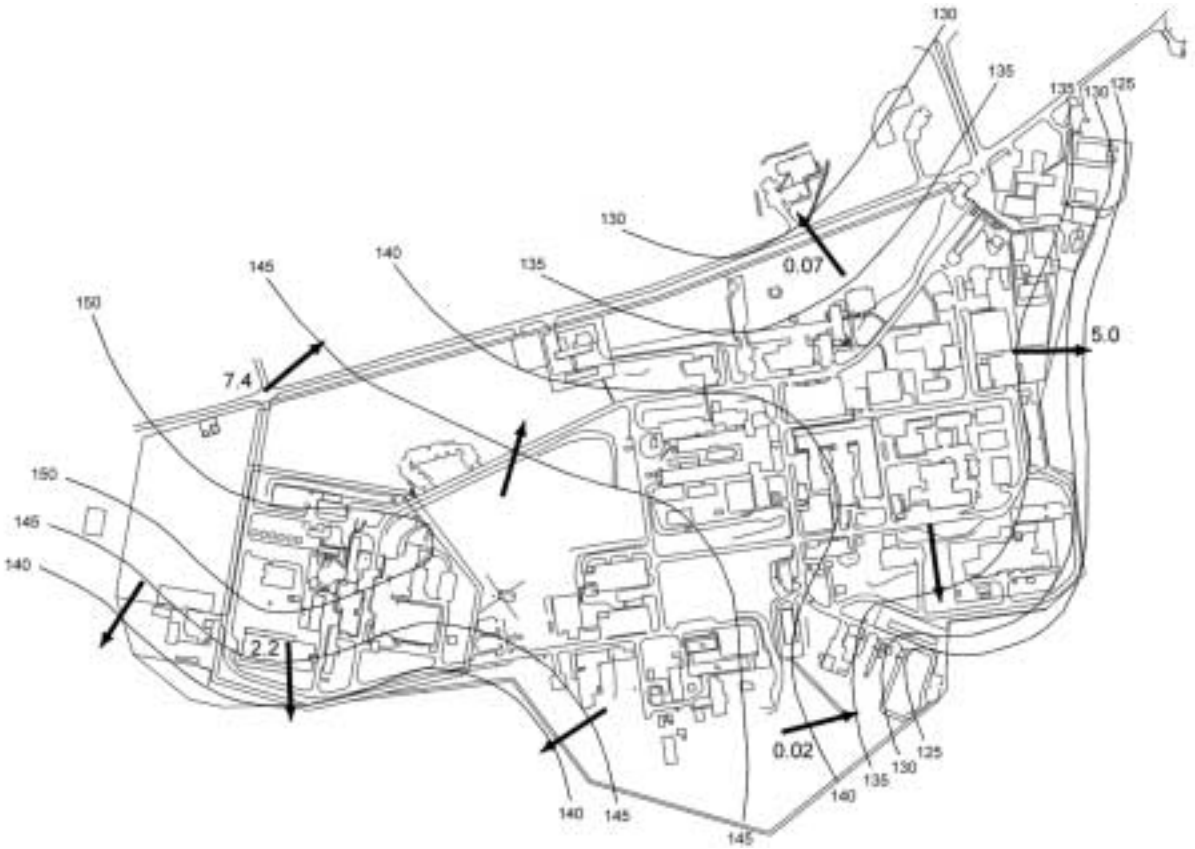

Figure 9. Potentiometric surface for the deeper sandstone aquifer, LHSTC, February 2000. Groundwater flow directions (arrows) and flow velocity (m/year) are also marked.

6.6.2 Rain and Evaporation Data

Rain and evaporation data for the LHSTC from 1994 to 2004 are summarised in **Table 28**. These data are used in the interpretation of groundwater hydrology for the LHSTC site. Monthly total rainfall (R Total; mm), the number of days on which rain fell (R Days), monthly potential evaporation (E Total; mm) and the maximum daily evaporation (E max; mm) are given.

6.6.3 Little Forest Burial Ground

Little Forest is located in a groundwater recharge area, so that rain water moves down-gradient from the site along pathways of least resistance. For the LFBG, these pathways include surface water runoff, groundwater flow via the zone of aeration and saturation in the Ashfield Shale layer, and infiltration into the underlying Hawkesbury Sandstone. As indicated by tritium measurements, the groundwater flows away from a South-West to North-East groundwater divide running through the central position of the burial trenches. **Figure 4** illustrates this divide and the likely groundwater flow paths.

Data from six-monthly sampling of groundwater field parameters are reported in **Tables 29** and **30**. In 2003-04, the groundwater pH ranged from 4.1 to 6.8, with a median of 5.6 ± 0.7, and EC ranged between 194 and 7697 µS/cm, with a median of 845 ± 1653 µS/cm. The LFBG tends towards slightly less acid groundwater than the LHSTC, with variable but generally higher salinity. This chemistry is a probably a natural consequence of the LFBG's position on the outcropping Ashfield shale. Measured Eh was generally positive, with a median of 170 ± 190, but some piezometers displayed low or negative Eh often associated with low oxygen concentrations. As for the LHSTC, stirring of sediment during sampling probably explains the generally turbid conditions reported for LFBG groundwater samples.

Routine six-monthly groundwater level monitoring and sampling from the LFBG piezometer network (**Figure 4**) is also undertaken to measure tritium, gross alpha and gross beta radioactivity and gamma-emitting radionuclides. Results of this monitoring are shown in **Tables 31** to **32**. Tritium activities in groundwater from the LFBG were below levels considered safe for drinking water in Australia in 2003-04. A maximum tritium concentration of 7290 Bq/L was recorded from piezometer BH10, north of the burial trenches. Gross alpha and gross beta activities in LFBG groundwater were below the levels prescribed for Class C surface waters in New South Wales. Gamma spectrometry of the unfiltered LFBG groundwater samples showed low levels of natural potassium-40. Cobalt-60 was found in samples from piezometer MB16, which lies between the main burial trenches, at levels similar to those reported in recent years. Americium-241 and caesium-137 were not detected in LFBG groundwater in 2003-04.

6.7 SOIL AND SEDIMENT

6.7.1 Bund Sediments

Sediments that accumulate in the stormwater bunds are removed at least once each year. These sediments are analysed, prior to their removal, for gross alpha, gross beta and gamma radioactivity (**Table 33**). The naturally-occurring gamma-emitters detected were potassium-40, beryllium-7 and members of the uranium-238 and thorium-232 decay series. The samples were also screened for fission and activation products which have occasionally been detected in previous years. As reported in sections 6.4.2 and 6.4.3, elevated levels of beta-gamma activity were measured in Bund C and this is reflected in the sediment, which contained cerium-144, caesium-137, cobalt-60, ruthenium-103, ruthenium-106, zirconium-95, niobium-95 and a trace of americium-241. All of the measured activity concentrations were far below exemption levels for classification of radioactive materials (ARPANSA 2004).

6.7.2 Sediment from Local Streams

Sediment was collected off-site near the confluence of Mill and Bardens Creeks, which ultimately drain the LFBG area. Levels of gross alpha, gross beta and gamma radioactivity were measured (**Table 19**) and showed only low levels of natural activity attributable to progeny of the uranium-238 and thorium-232 decay series and potassium-40.

6.7.3 Gamma Dose-Rate Survey – Little Forest Burial Ground

Dose-rates over all of the trenches (**Figure 4**) were measured in September 2003 using a hand-held meter at near-ground level (**Table 34**). Recorded dose-rates ranged from 0.06 to 0.20 μSv/hour and are consistent with background readings taken at the LFBG gate, approximately 200 metres away from the trench area.

On 17 November 2003, in response to vandalism at the LFBG, three samples of soil were collected from the trench area. The samples were analysed for gross alpha, gross beta and gamma radioactivity. The average gross alpha and beta activities were 0.76 and 0.46 Bq/g, respectively. The gamma results showed typical levels of natural background radioactivity. All of the results indicate that there was no mobilisation of radioactivity as a result of this incident. The potential radiological exposure to members of the public from the LFBG continues to be assessed as negligible.

6.7.4 Gamma Dose-Rate Survey - Main Discharge Pipeline

The results of the MDP pipeline dose-rate surveys for July 2003 to June 2004 are summarised in **Table 35**. The measured MDP dose-rates along the pipeline ranged from 0.05 to 0.14 μSv/hour, and were within the range measured for natural background radiation. Minor, slow leaks from joints 8 and 13 were reported and rectified on 18 September 2003. Soil samples were collected near the joints and analysed for gamma-emitters. Normal environmental concentrations of naturally-occurring potassium-40 and the uranium-238 and thorium-232 decay series were found, in addition to traces of americium-241, caesium-137 and cobalt-60. There were no short-lived radionuclides present, making it difficult to determine whether the low levels of activity found were of recent origin. The maximum levels found in the soils were 1-2% of the exempt activity concentrations for americium-241, caesium-137 and cobalt-60 (1,000; 10,000 and 10,000 Bq/kg respectively) published by ARPANSA (2004). The occasional occurrence of such leaks is a normal consequence of the natural expansion and contraction of the metal pipes with temperature variations. The pipeline has since undergone extensive maintenance including tightening of the joints, rust-proofing and painting.

6.8 BIOTA (POTTER POINT)

Treated sewage effluent from the Sutherland Shire, including low-level effluent from the LHSTC, passes through the Cronulla STP and is discharged at Potter Point (**Figure 1**, inset). Sampling of fish, algae (seaweed) and barnacles continued at the Potter Point ocean outfall and a reference site at The Royal National Park from July 2003 to June 2004, with authorisation from NSW Fisheries. These organisms represent different levels in the food chain and are known to concentrate a variety of elements, including radionuclides, from their environment. Blackfish, also known as luderick (*Girella sp.*) were filleted and skinned, green algae (mainly *Ulva sp.* or *Enteromorpha sp.*) and surf barnacles (*Tesseropera rosea*) were left whole and unwashed. All samples were dried, ground and analysed for gamma-emitting radioisotopes (**Tables 36-38**).

The radioactivity measured in marine fish, algae and barnacles sampled at Potter Point in 2003-04 was of natural origin, apart from the low levels of iodine-131 found in the algae. Iodine-131 is a medical radioisotope used in the treatment of thyroid cancer. ANSTO's liquid effluent is therefore not the only source of iodine-131 in the Sutherland Shire sewerage system. Only naturally occurring radionuclides were detected in samples collected from the reference site.

6.9 A DECADE OF MONITORING

Monitoring data are usually collected with the aim of satisfying requirements for compliance and reporting over periods of a year or less. The same data provide a measure of ongoing trends and year to year variation. Examples of longer term data from ANSTO's environmental monitoring are set out below.

6.9.1 Airborne Dose

The modelling of airborne dose to the public integrates data for airborne emissions with meteorological measurements, within the concept of exposure pathways to critical groups. Thus, a single performance index is generated for the principal source of potential radiation exposure

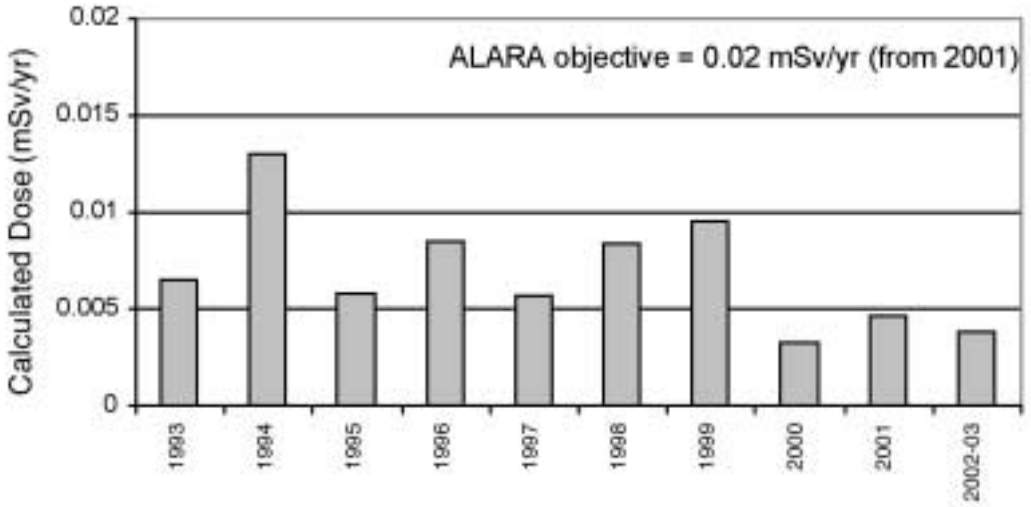

Figure 10. Maximum annual effective dose from LHSTC airborne discharges at the 1.6 km boundary of ANSTO's buffer zone, 1993 to 2003.

to members of the public from routine ANSTO operations at the LHSTC. **Figure 10** shows a decade of data for the maximum annual airborne effective dose at the 1.6 km boundary of ANSTO's buffer zone.

The data show that the calculated airborne doses at 1.6 km have all been below the recently adopted ALARA objective of 0.02 mSv/year, and typically less than half this value. The lowest effective doses to the public from routine ANSTO operations have occurred in the last three years of the data.

6.9.2 Tritium in Liquid Effluent

Figure 11 shows the average monthly concentration of tritium in ANSTO's liquid effluent discharges to the sewer from the LHSTC.

The concentration of tritium in liquid effluent released to the sewer has been consistently less than the limit specified by the present trade waste agreement, typically less than a quarter of this limit. Peaks in 2000 and 2001 were associated with routine maintenance of primary coolant circuit components carried out during scheduled reactor shutdowns. Periods of particularly low tritium concentrations are evident for 1999 and 2002-03.

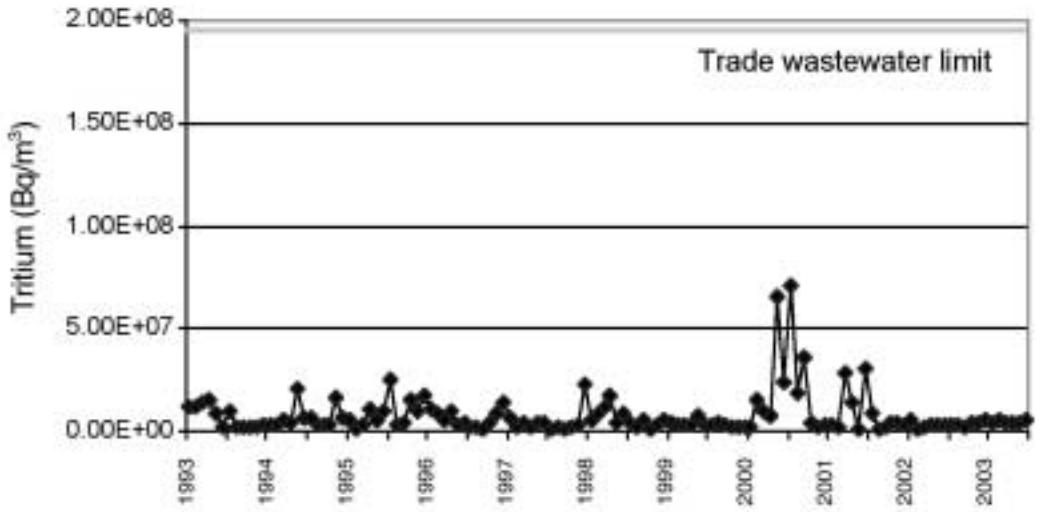

Figure 11. Monthly average tritium concentrations in liquid effluent discharges from the LHSTC, 1993 to 2003.

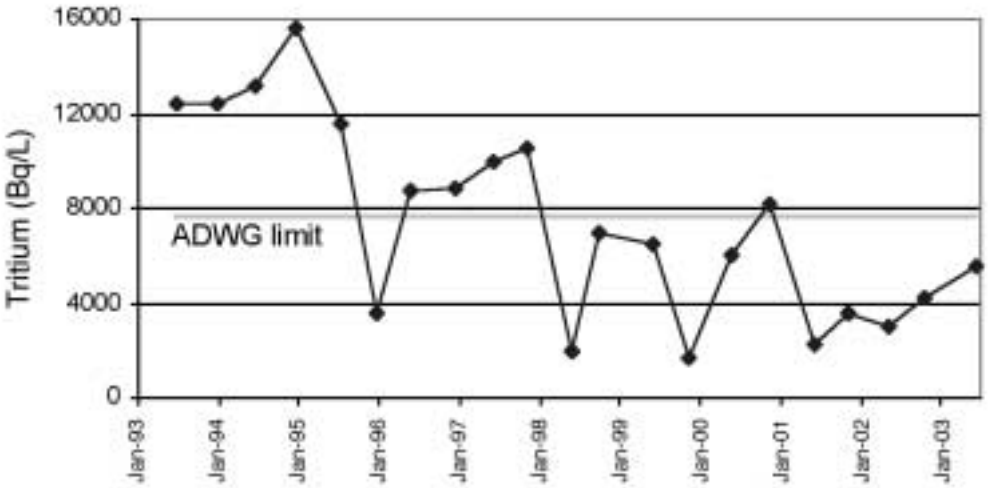

Figure 12. Tritium in groundwater from LFBG piezometer MB16, 1993 to 2003, and the Australian Drinking Water Guideline for tritium.

6.9.3 Tritium in Groundwater at the LFBG

Figure 12 shows the concentration of tritium in water sampled from piezometer MB16 at the LFBG. The downward trend for tritium in groundwater from MB16 probably reflects both radioactive decay and dilution of whatever tritium-containing material was initially buried. MB16 is situated in the middle of the main burial trenches and has generally represented the maximum tritium concentration for any of the piezometers sampled at the LFBG. In recent years, this maximum tritium concentration has fallen below the ADWG level for tritium of 7600 Bq/L.

6.9.4 Tritium in Stormwater

The tritium concentration in a natural pool some sixty metres downstream of stormwater Bund C has been measured for more than a decade (see **Figure 13**).

As stated previously, tritium is routinely detected in LHSTC stormwater, principally as a result of rain-out of tritiated water vapour released to the atmosphere. Clearly, the concentrations detected in the past decade have remained well below levels considered acceptable in human drinking water in Australia. Peaks in the graph are most likely to be associated with rainfall but the interplay between atmospheric tritium and tritium detected at MDP+60m will be conditioned, amongst other things, by wind direction, rainfall intensity and recent rain history.

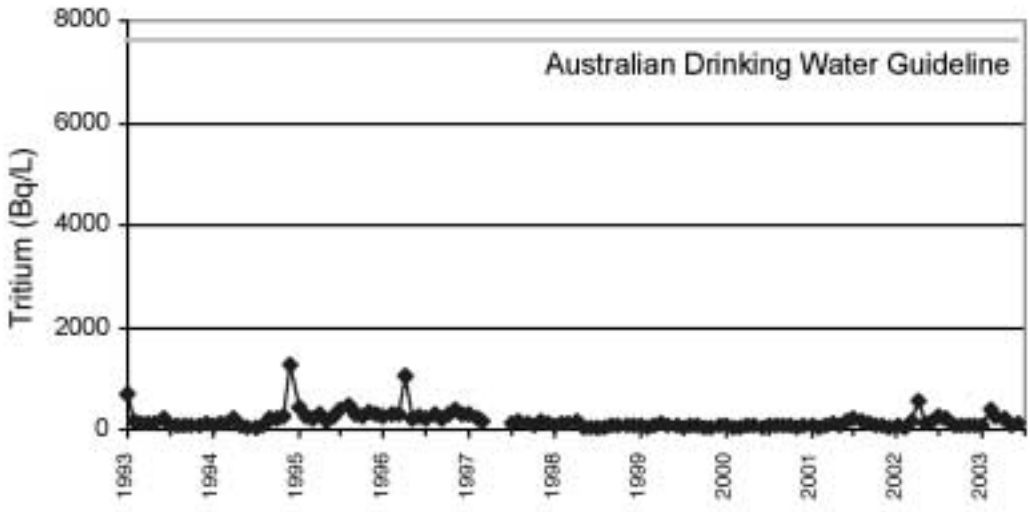

Figure 13. Tritium in surface waters from MDP+60m, LHSTC, 1993 to 2003.

7. Potential Doses to the Public and Environment

The principal sources of potential radiation exposure to members of the public from routine ANSTO operations at the LHSTC and NMC are from airborne emissions and low-level liquid effluent discharges. Meteorological and airborne emissions monitoring data provide the necessary input to the atmospheric dispersion and dose-estimation model, PC-Cream, which is used to compute the effective dose to hypothetical individuals due to the routine airborne release of radionuclides. The conservative assumptions routinely used in the PC-Cream dose-modelling are explained in Hoffmann and Loosz (2002).

Currently, there is no internationally agreed approach to assessing doses to non-human species and no established guidelines against which to determine the risks of such doses. Following the ICRP (1991), it is assumed here that demonstrating protection of humans from the potential effects of ionising radiation also demonstrates adequate protection of the environment.

7.1 AIRBORNE DISCHARGES

The annual effective doses to hypothetical individuals potentially exposed to radiation in routine airborne discharges from the LHSTC in 2003-04 were modelled, based on the LHSTC stack discharge data and concurrent meteorological information (**Table 39**). For the purposes of this report, the critical group of members of the public potentially affected by routine airborne releases comprises hypothetical individuals living around the 1.6 km buffer zone boundary and for whom the estimated effective doses are presented in **Table 39** – people working at the LHSTC are not considered here. The estimated effective doses to this critical group from routine airborne emissions ranged from 0.0006 to 0.0038 mSv/year, with a median of 0.0017 ± 0.0017 mSv/year.

The maximum estimated effective dose for the critical group was 0.0038 mSv/year to the East-Northeast, and was therefore less than 20% of the ALARA objective of 0.02 mSv/year and much lower than the public dose limit of 1 mSv/year and the natural background in Australia of ~1.5 mSv/year (not including medical investigations; Webb *et al.* 1999).

Figure 14 shows the public dose from LHSTC airborne emissions estimated for the critical group of hypothetical individuals on a 1.6 km radius from HIFAR, relative to the ALARA objective, for 2003-04.

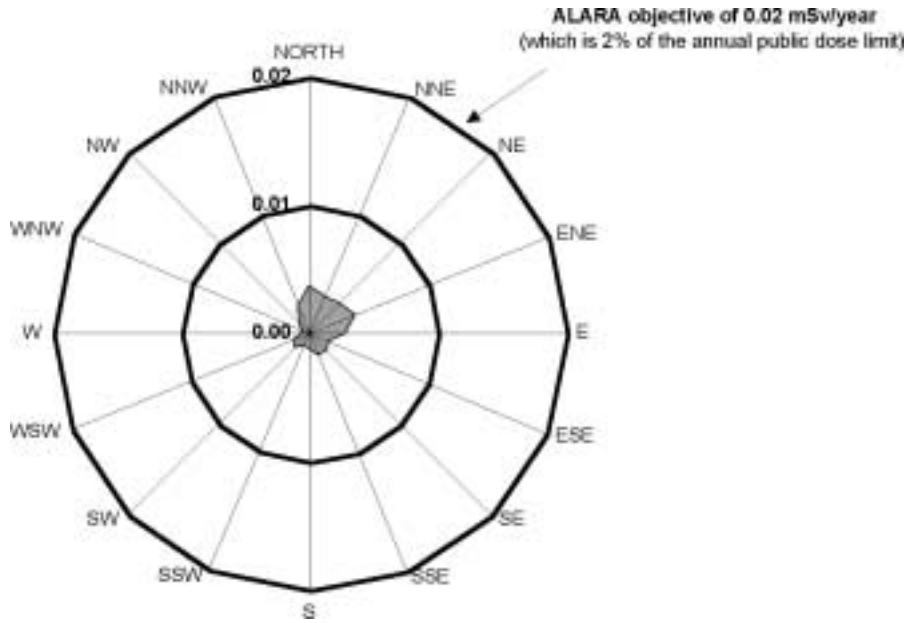

Figure 14. Estimated effective dose to the public, at a 1.6 km radius from HIFAR (mSv/year), from routine LHSTC airborne discharges, July 2003 to June 2004.

Thermoluminescent dosimeters placed around LHSTC and at some local residences also indicated that the external gamma radiation levels at residential locations in the vicinity of the LHSTC were not noticeably affected by ANSTO's operations. Airborne discharges from the NMC were well below the relevant four-weekly, quarterly and annual notification levels, thereby ensuring that the potential dose to humans is below the ALARA objective of 0.02 mSv/year.

7.2 LIQUID EFFLUENT DISCHARGES

The effective dose-rates to the critical group of members of the public potentially exposed to radiation from routine liquid effluent discharges from the LHSTC were recently calculated to be no more than a quarter of the minimum dose estimated for members of the public potentially exposed to airborne emissions from the LHSTC (Hoffmann *et al.* 2003).

Liquid effluent discharged to the Sydney sewerage system from the NMC ultimately enters the sea off-shore via the deep ocean outfalls. The small amounts of short-lived radioactivity in the effluent from the NMC and the high dilution in the sewage system means that any potential doses are very small. Since the release is to the ocean, off-shore, there is unlikely to be any significant environmental pathway to humans, such as through the consumption of seafood.

8. Conclusion

For the period from July 2003 to June 2004, the estimated potential doses to members of the public from airborne discharges at the LHSTC are only a very small fraction of the radiation dose received by everyone each year from naturally-occurring sources of radiation. The monitoring results from Potter Point confirm that the potential radiation dose to members of the public as a result of ANSTO's liquid effluent discharges to the sewer is also very low. The levels of tritium in groundwater and stormwater at the LHSTC (including the LFBG) are less than Australian drinking water guidelines. The airborne and liquid effluent emissions from the NMC, from July 2003 to June 2004, were below the ARPANSA-approved notification levels and NSW DEC limits, respectively. It is concluded that ANSTO's operations at the LHSTC and the NMC make only a very small addition to the natural background radiation dose, even for the comparatively few members of the public identified as potentially exposed to radionuclides entering the environment from ANSTO sites.

9. Acknowledgements

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DATA TABLES

Table 1. MEDIAN DETECTION LIMITS FOR RADIOLOGICAL ANALYSES OF ENVIRONMENTAL MEDIA, July 2003 to June 2004

Environmental Media	Gamma-emitters						Gross Alpha	Gross Beta	Tritium	Pu-239/240 (Bq total)	Stable Beryllium (µg total)
	Am-241	I-131	Cs-137	Co-60	K-40	Be-7					
WATERS (Bq/L)	0.013	-	0.022	0.029	0.567	0.082	0.04	0.14	10	-	
SOIL / SEDIMENT (Bq/g)	0.001	-	0.002	0.002	0.125	0.012	-	-	-	-	
FISH (Bq/kg fresh weight)	0.34	0.6	0.53	0.46	134	2.4	-	-	-	-	
ALGAE (seaweed) (Bq/kg fresh weight)	0.25	1.9	0.29	0.57	202	2.1	-	-	-	-	
BARNACLES (Bq/kg fresh weight)	0.59	1.0	0.64	0.92	37	5.6	-	-	-	-	
MAYPACKS (Bq/m^3)	-	0.0025	-	-	-	-	-	-	-	-	
AIRBORNE PARTICLES (High-volume air filters)	-	-	-	-	-	-	-	-	-	0.001	0.06

Notes:
1. The radioactivity analyses results of the environmental monitoring program are reported using the principles of counting decision limits endorsed by Gilmore and Hemingway (1995). These decision levels are used to determine the statistical significance of a sample count based upon the uncertainty of the blank or background. Since environmental media exhibit natural variation, the minimum detectable activity (MDA) is calculated for each sample or batch analysed, and the median values for different sample matrices are given above.
2. In the following data tables, "< MDA" indicates that the result was below the minimum detectable activity, calculated with 95% confidence.

Table 2 . ANNUAL AIRBORNE ACTIVITY DISCHARGE REPORT, LHSTC AND NMC, June 2003 to June 2004

	Particulates		Gases and Vapours																
STACK	Gross Alpha (MBq)	Gross Beta (MBq)	I-131 (MBq)	Tritium (GBq)	Ar-41 (TBq)	Hg-197 (MBq)	Hg-203 (MBq)	As-76 (MBq)	Br-82 (MBq)	I-132 (MBq)	I-133 (MBq)	Xe-133 (TBq)	Xe-135 (TBq)	Xe-135m (TBq)	Kr-85m (TBq)	Kr-87 (GBq)	Kr-88 (TBq)	F-18 (GBq)	I-123 (GBq)	All Other Nuclides (MBq)
3	0.005	N.D.																		1.71
	1.0%	-																		0.3%
15A	N.D.	1.31	6.97	2808.00	109.80	88.74	7.26	161.40	6.70											
	-	2.2%	17.4%	28.1%	61.0%	31.7%	18.2%	64.6%	26.8%											
15M	N.D.	N.D.	1.52	255.60	11.37															
	-	-	15.2%	56.8%	56.9%															
19S	N.D.	N.D.	12.16																	N.D.
	-	-	24.3%																	-
19D	N.D.	N.D.	0.27																	N.D.
	-	-	0.5%																	-
20	0.004	0.79		40.08																39.60
	< 0.1%	1.1%		18.2%																7.9%
20B	N.D.	N.D.																		0.8
																				0.2%
21A	N.D.	N.D.																		0.07
	-	-																		< 0.1%
21B	N.D.	N.D.																		0.08
	-	-																		< 0.1%
23A	N.D.	9.15	5624																	N.D.
	-	2.7%	17.0%																	-
23B	N.D.	N.D.	4.88																	N.D.
	-	-	4.4%																	-
41A	N.D.	N.D.																		11.10
	-	-																		2.2%
41B	N.D.	N.D.																		3.10
	-	-																		0.6%
54	N.D.	N.D.	20890							107100	1718	410.50	45.60	65.60	23.20	N.D.	N.D.			N.D.
	-	-	74.6%							44.6%	11.5%	146.6%	11.4%	16.4%	35.7%	-	-			-
56	N.D.	N.D.																		2.46
	-	-																		0.5%
57	N.D.	N.D.		25.4																1.17
	-	-		11.5%																0.2%
NMC																		5.3	47.82	34.67
																		2.12%	47.82%	6.9%

Notes:
1. Percentages reported are the discharge as a percentage of the annual Notification Level. ND = Not Detected.
2. The "All Other Nuclides" column includes all nuclides for which no specific notification level exists, ie it may include some of the other listed nuclides.
3. The NMC sampling period was 30 June 2003 to 25 June 2004. The LHSTC sampling period was 24 June 2003 to 22 June 2004.
4. The stack for Bld 20B, the new waste treatment & packaging facility, was commissioned in June 2004.

Table 3. RADIOACTIVITY IN LIQUID EFFLUENT DISCHARGED TO THE SYDNEY WATER SEWER, LHSTC, July 2003 to June 2004

Month	Total Volume Discharged (m^3)	Average Concentration in Discharges			Average Monthly Concentration Quotient
		Alpha (Bq/m^3)	Beta (Bq/m^3)	Tritium (Bq/m^3)	
July 2003	9445	$< 6.08 \times 10^2$	6.39×10^3	4.06×10^6	< 0.12
August 2003	6640	$< 2.79 \times 10^2$	2.41×10^3	3.62×10^6	< 0.06
September 2003	6755	$< 1.00 \times 10^2$	4.46×10^3	3.66×10^6	< 0.06
October 2003	6650	$< 1.00 \times 10^2$	4.16×10^3	6.13×10^6	< 0.07
November 2003	6000	$< 1.00 \times 10^2$	3.78×10^3	4.31×10^6	< 0.06
December 2003	6724	$< 1.00 \times 10^2$	4.56×10^3	4.35×10^6	< 0.07
January 2004	5628	$< 1.00 \times 10^2$	9.27×10^2	3.53×10^6	< 0.03
February 2004	6843	$< 1.00 \times 10^2$	2.04×10^3	4.14×10^6	< 0.05
March 2004	5510	$< 1.00 \times 10^2$	6.88×10^3	8.30×10^6	< 0.11
April 2004	4888	$< 1.00 \times 10^2$	1.08×10^4	1.27×10^7	< 0.16
May 2004	4395	$< 1.00 \times 10^2$	6.15×10^3	5.86×10^6	< 0.09
June 2004	4494	$< 1.00 \times 10^2$	7.27×10^3	5.68×10^6	< 0.10
Regulatory Limit: Activity Concentration Equivalent at ANSTO		1.25×10^4 (as Ra-226)	1.25×10^5 (as Sr-90)	1.95×10^8	1.00

Notes:
1. Average concentrations are calculated from the alpha, beta and tritium results for all the pipeline samples taken for that month. The pipeline samples are flow proportional samples, taken whenever effluent is discharged to the sewer.
2. Alpha-emitting nuclides are assumed to be all Ra-226 (*ie* possible worst case) when calculating the concentration quotient.
3. Beta-emitting nuclides are assumed to be all Sr-90 (*ie* possible worst case) when calculating the concentration quotient.
4. The Concentration Quotient is the sum of the average monthly concentrations of alpha, beta and tritium radioactivity in the liquid effluent divided by the Activity Concentration Equivalent for that radionuclide. The final quotient term must be no greater than one to comply with the requirements of the Consent to Discharge Industrial Trade Wastewater agreement with Sydney Water.
5. All discharges were below the required Activity Concentration Equivalents at ANSTO (which are based on the WHO Guidelines for Drinking-Water Quality (WHO 1993).

Table 4. GAMMA-EMITTERS IN LIQUID EFFLUENT, MONTHLY PIPELINE COMPOSITE SAMPLES, LHSTC, July 2003 to June 2004

	Gamma-emitters (Bq/L)								
MONTH	**Ce-144**	**Co-60**	**Cr-51**	**Cs-134**	**Cs-137**	**I-131**	**Ra-226**	**Pb-210**	**Ra-228**
July 2003	< MDA	0.58 ± 0.13	< MDA	< MDA	3.42 ± 0.14	0.31 ± 0.06	6.56 ± 1.12	< MDA	< MDA
August 2003	< MDA	0.44 ± 0.07	3.98 ± 0.48	< MDA	2.71 ± 0.11	< MDA	3.92 ± 0.94	< MDA	< MDA
September 2003	< MDA	0.37 ± 0.09	0.53 ± 0.12	< MDA	2.12 ± 0.06	< MDA	< MDA	< MDA	< MDA
October 2003	< MDA	< MDA	< MDA	< MDA	5.77 ± 0.12	< MDA	4.14 ± 0.83	< MDA	< MDA
November 2003	< MDA	< MDA	< MDA	< MDA	< MDA	< MDA	5.79 ± 0.75	< MDA	< MDA
December 2003	< MDA	0.38 ± 0.08	< MDA	< MDA	4.43 ± 0.09	0.37 ± 0.07	< MDA	< MDA	< MDA
January 2004	< MDA	< MDA	< MDA	< MDA	2.84 ± 0.11	< MDA	< MDA	< MDA	< MDA
February 2004	< MDA	< MDA	< MDA	< MDA	0.36 ± 0.05	< MDA	< MDA	< MDA	< MDA
March 2004	< MDA	< MDA	< MDA	< MDA	1.55 ± 0.05	< MDA	< MDA	< MDA	< MDA
April 2004	< MDA	< MDA	< MDA	< MDA	6.06 ± 0.06	< MDA	< MDA	< MDA	< MDA
May 2004	< MDA	< MDA	< MDA	< MDA	1.97 ± 0.07	0.15 ± 0.02	< MDA	< MDA	< MDA
June 2004	< MDA	< MDA	< MDA	< MDA	3.03 ± 0.06	0.32 ± 0.03	< MDA	< MDA	< MDA

Notes:
1. Gamma spectrometry was performed on the "monthly pipeline composite", which is made up of volume-proportional samples from all treated liquid effluent discharges during a given month.
2. Measurement uncertainties are quoted at one standard deviation.
3. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Median MDA values for the relevant radionuclides are as follows: 0.38 for Ce-144, 0.13 for Co-60, 0.68 for Cr-51, 0.09 for Cs-134, 0.21 for Cs-137, 0.09 for I-131, 1.79 for Ra-226, 1.37 for Pb-210, and 0.57 for Ra-228.

Table 5. NON-RADIOACTIVE COMPONENTS OF LIQUID EFFLUENT DISCHARGED TO THE SYDNEY WATER SEWER, LHSTC, July 2003 to June 2004

Parameter	**Concentration** (mg/L) **July 2003 to June 2004**			**Standard for Acceptance** (mg/L)
	Mean	**Median**	**Range**	
Suspended Solids	23.8	13.0	2 - 135	**600**
pH	7.2	7.1	6.5 – 10.0	**7 – 10**
Ammonia	11.8	12.2	< 0.5 – 26.2	**50**
BOD	18.3	15.0	3.0 – 55.0	**230**
Grease	5.5	5.0	< 5 - 12	**110**
Zinc	0.1	0.1	< 0.1 – 1.1	**5**
Total Dissolved Solids	354	364	226 - 482	**10 000**

Notes:

1. The discharge of effluent to sewer is governed by an agreement between ANSTO and the Sydney Water Corporation: *Consent to Discharge Industrial Trade Wastewater (Consent number 4423), Dec. 2003*. The effluent is sampled every 4th discharge day. Of the samples analysed, 95% must be less than or equal to the Standards for Acceptance.
2. The domestic concentration applies for biological oxygen demand (BOD).
3. Total Dissolved Solids were measured from January 2004 in accordance with the December 2003 trade waste agreement.

Table 6. RADIOACTIVITY IN LIQUID EFFLUENT DISCHARGED TO THE SEWER, NMC, July 2003 to June 2004

Month	Volume Discharged (m^3)	Average pH	Monthly Average Concentration in Liquid Effluent (MBq/m^3)					
			Tl-201	**Tl-202**	**Ga-67**	**Co-57**	**Zn-65**	**I-123**
July 2003	8	7.9	1.77	3.69	ND	0.87	0.50	ND
August 2003	7	8.0	7.94	1.05	1.40	0.32	0.34	ND
September 2003	6	7.0	1.20	0.71	3.42	0.27	0.19	ND
October 2003	6	7.0	0.33	0.39	0.15	0.40	0.10	ND
November 2003	4	7.3	17.14	31.39	0.53	7.91	1.40	0.79
December 2003	6	7.3	10.09	9.97	0.48	2.67	0.94	ND
January 2004	9	7.3	2.67	3.42	17.15	3.40	0.42	ND
February 2004	6	7.3	ND	0.26	0.02	0.41	0.19	ND
March 2004	5	8.6	0.60	0.17	ND	0.55	0.23	ND
April 2004	5	7.2	7.29	2.86	9.97	0.91	0.19	ND
May 2004	7	7.7	2.17	2.37	0.23	2.06	0.32	ND
June 2004	7	8.1	4.71	1.77	0.71	1.41	0.49	ND
Mean	6	7.6	4.66	4.84	2.84	1.77	0.44	0.07
Median	6	7.3	2.42	2.07	0.50	0.89	0.33	ND
NSW EPA Monthly Limits	**NA**	**7 – 10**	**200**	**100**	**600**	**400**	**100**	**6.00**

Notes:
1. ND - not detected.
2. NA - not applicable.

Table 7. EFFLUENT DILUTION STUDIES, CRONULLA SEWAGE TREATMENT PLANT AND POTTER POINT, July 2003 to June 2004

CRONULLA SEWAGE TREATMENT PLANT

Date	Effluent release from LHSTC			Tritium activity at LHSTC release point (Bq/L)	Peak tritium activity at CSTP Interstage (Bq/L)	Dilution ratio at CSTP Interstage
	Start time (h:mm)	Duration (h:mm)	Volume (kL)			
29-3-04	13:50	2:29	200	23160	360	64:1
30-3-04	15:51	5:51	260	38370	840	46:1
1-4-04	12:00	2:46	215	45880	600	76:1
2-4-04	9:45	2:47	222	15630	372	42:1

POTTER POINT OCEAN OUTFALL

Date	Sampling start time (h:mm)	Sampling end time (h:mm)	Sampling distance from outfall (m)			Maximum tritium level (Bq/L)
			Site 1	Site 2	Site 3	
1-4-04	8:30	15:00	5	162	432	4.1
22-6-04	10:00	14:00	80	162	432	5.8

Notes:
1. Peak tritium activity and dilution are reported for samples collected at the 'interstage' location in the Cronulla STP, which follows the sedimentation tank in the vicinity of the interstage lift pump.

Table 8. AMBIENT IODINE-131 IN AIR, LHSTC, July 2003 to June 2004

Sampled during the week ending:	**I-131 in Air** (Bq/m^3)	Sampled during the week ending:	**I-131 in Air** (Bq/m^3)	Sampled during the week ending:	**I-131 in Air** (Bq/m^3)
1-7-03	< MDA	3-11-03	< MDA	9-3-04	< MDA
8-7-03	< MDA	11-11-03	< MDA	16-3-04	< MDA
15-7-03	< MDA	18-11-03	< MDA	23-3-04	< MDA
22-7-03	< MDA	25-11-03	< MDA	30-3-04	< MDA
29-7-03	< MDA	2-12-03	< MDA	6-4-04	< MDA
5-8-03	< MDA	9-12-03	< MDA	13-4-04	< MDA
12-8-03	< MDA	16-12-03	< MDA	20-4-04	< MDA
19-8-03	< MDA	23-12-03	< MDA	27-4-04	< MDA
26-8-03	< MDA	30-12-03	< MDA	4-5-04	< MDA
2-9-03	< MDA	6-1-04	< MDA	11-5-04	< MDA
9-9-03	< MDA	13-1-04	< MDA	18-5-04	< MDA
16-9-03	< MDA	20-1-04	< MDA	25-5-04	< MDA
23-9-03	< MDA	28-1-04	< MDA	1-6-04	< MDA
30-9-03	< MDA	4-2-04	< MDA	8-6-04	0.009
7-10-03	< MDA	10-2-04	< MDA	15-6-04	0.003
14-10-03	< MDA	17-2-04	< MDA	22-6-04	< MDA
21-10-03	< MDA	24-2-04	< MDA	29-6-04	< MDA
28-10-03	< MDA	2-3-04	< MDA		

Notes:
1. Four air samplers are located along the eastern boundary of the LHSTC site, see Figure 2.
2. Results are conservative since any I-131 activity is corrected for decay from the first day of the sampling week.
3. < MDA indicates that the result was below the minimum detectable activity. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 9. RADIOACTIVITY IN AIRBORNE PARTICLES, LFBG, July 2003 to June 2004

Sampling Period	Equivalent Volume (m^3)	(% of Filter)	Beryllium (µg total)	(µg/m^3)	Plutonium-239/240 (Bq total)	(Bq/m^3)
July – Dec 03	829	25	MDA	$< 7.2 \times 10^{-5}$	MDA	$< 1.2 \times 10^{-6}$
Jan – Mar 04	451	25	MDA	$< 1.3 \times 10^{-4}$	MDA	$< 2.2 \times 10^{-6}$
Apr – Jun 04	586	25	0.04	6.8×10^{-5}	MDA	$< 1.7 \times 10^{-6}$

Notes:
1. Airborne particulates were collected using a mobile high-volume air sampler and samples were accumulated on a single filter over a period of 3 or 6 months. The sampling duration and frequency was approximately 4 hours, every 2 weeks.
2. The Worksafe Australia Exposure Standard for atmospheric contaminants such as beryllium in air is 2 µg/m^3 (applicable to workers exposed 8 hours per day, 50 weeks per year).
3. The limit of detection for Pu-239/240 in Bq/m^3 would equate to a committed effective dose to adults of < 0.0002 mSv/year, or < 0.02% of the allowable public dose limit of 1 mSv/year.
4. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1. The concentrations were calculated using the actual MDA and the volume of air sampled.

Table 10. EXTERNAL GAMMA RADIATION, LHSTC AND LOCAL AREA, ANNUAL EFFECTIVE DOSE for 2002-03 and 2003-04

ANSTO Environmental Thermoluminescent Dosimeters			
LHSTC Dosimeter Location: on-site		**Annual Effective Dose** (mSv/year)	
		2002-03	2003-04
1	HIFAR fence - south east	1.13 ± 0.04	1.05 ± 0.04
2	HIFAR fence - south	2.94 ± 0.11	3.06 ± 0.12
3	Perimeter fence - west	2.15 ± 0.08	2.27 ± 0.09
4	HIFAR fence - west	1.45 ± 0.06	1.41 ± 0.05
5	HIFAR fence - north west	1.24 ± 0.05	1.28 ± 0.05
6	Perimeter fence - north A	1.05 ± 0.04	0.94 ± 0.04
7	Internal fence - north	1.09 ± 0.04	1.09 ± 0.04
8	Perimeter fence - north B	1.50 ± 0.06	1.39 ± 0.05
9	Perimeter fence - north east	0.93 ± 0.04	0.90 ± 0.03
10	Perimeter fence - east	0.93 ± 0.04	1.03 ± 0.04
11	Perimeter fence - south east	0.97 ± 0.04	0.95 ± 0.04
12	Corner of Curie and Roentgen St	1.15 ± 0.04	1.36 ± 0.05
13	Perimeter fence - south	0.94 ± 0.04	0.82 ± 0.03
14	HIFAR fence - east	1.03 ± 0.04	1.14 ± 0.04
15	HIFAR fence - north east	1.10 ± 0.04	1.24 ± 0.05
	Dosimeter Location: off-site		
16	Private house - Barden Ridge	0.98 ± 0.04	0.88 ± 0.03
17	Private house - Engadine	1.24 ± 0.05	1.13 ± 0.04
18	Private house - Woronora	1.09 ± 0.04	0.96 ± 0.04
19	Cronulla Sewage Treatment Plant	0.71 ± 0.03	0.67 ± 0.03

Notes:
1. Refer to Figure 2 for the current locations of dosimeters 1 to 15 at the LHSTC. In 2002, dosimeters 3 and 5 were moved to their current locations due to the construction of the RRR. Number 17 was relocated from Engadine to Yarrawarrah in January 2004.
2. The uncertainties have been estimated (at the 95% confidence level) from the standard deviation of the results for several dosimeters placed at the same location.
3. The data (absorbed dose to air in mGy) were converted to effective dose for adults (mSv) using a conservative conversion factor of 1.

Table 11. EXTERNAL GAMMA RADIATION, NMC AND LOCAL AREA, ANNUAL EFFECTIVE DOSE for 2002-03 and 2003-04

ANSTO Environmental Thermoluminescent Dosimeters			
NMC Dosimeter Location:		**Annual Effective Dose** (mSv/year)	
		2002-03	2003-04
1	Front entrance	1.89 ± 0.07	1.86 ± 0.07
2	East wall	1.51 ± 0.06	1.57 ± 0.06
3	Stair on north wall	1.80 ± 0.07	1.68 ± 0.06
4	West wall	1.85 ± 0.07	1.65 ± 0.06

Notes:
1. The uncertainties have been estimated (at the 95% confidence level) from the standard deviation of the results for several dosimeters placed at the same location.
2. The data (absorbed dose to air in mGy) were converted to effective dose for adults (mSv) using a conservative conversion factor of 1.

Table 12. TRITIUM IN STORMWATER BUNDS, MONTHLY COMPOSITES, LHSTC July 2003 to June 2004

	TRITIUM (Bq/L)		
Month	**BUND A**	**BUND B**	**BUND C**
July 2003	60 ± 10	50 ± 10	110 ± 10
August 2003	50 ± 10	80 ± 10	90 ± 10
September 2003	30 ± 10	40 ± 10	60 ± 10
October 2003	290 ± 10	70 ± 10	120 ± 10
November 2003	80 ± 10	50 ± 10	160 ± 10
December 2003	220 ± 10	40 ± 10	90 ± 10
January 2004	380 ± 10	60 ± 10	30 ± 10
February 2004	300 ± 10	30 ± 10	50 ± 10
March 2004	610 ± 20	100 ± 10	90 ± 10
April 2004	150 ± 10	30 ± 10	180 ± 10
May 2004	20 ± 10	90 ± 10	90 ± 10
June 2004	30 ± 10	40 ± 10	70 ± 10

Notes:
1. Refer to Figure 2 for the locations of the bunds. One litre was collected daily from each bund before it was discharged (except weekends and public holidays). These daily samples were combined to form a monthly composite from each bund for tritium analysis.

Table 13. TRITIUM IN STORMWATER, BUND C, LHSTC, July 2003 to June 2004

Date	**Tritium** (Bq/L)	Date	**Tritium** (Bq/L)	Date	**Tritium** (Bq/L)
1-7-03	120 ± 10	3-11-03	70 ± 10	9-3-04	140 ± 10
8-7-03	90 ± 10	11-11-03	180 ± 10	16-3-04	100 ± 10
15-7-03	130 ± 10	18-11-03	450 ± 20	23-3-04	170 ± 10
22-7-03	120 ± 10	25-11-03	120 ± 10	30-3-04	90 ± 10
29-7-03	100 ± 10	2-12-03	120 ± 10	6-4-04	80 ± 10
5-8-03	80 ± 10	9-12-03	220 ± 10	13-4-04	170 ± 10
12-8-03	80 ± 10	17-12-03	40 ± 10	20-4-04	230 ± 10
19-8-03	80 ± 10	23-12-03	50 ± 10	27-4-04	230 ± 10
26-8-03	120 ± 10	30-12-03	40 ± 10	4-5-04	210 ± 10
2-9-03	120 ± 10	6-1-04	20 ± 10	11-5-04	210 ± 10
9-9-03	140 ± 10	13-1-04	20 ± 10	21-5-04	130 ± 10
16-9-03	160 ± 10	20-1-04	20 ± 10	25-5-04	200 ± 10
23-9-03	140 ± 10	28-1-04	30 ± 10	1-6-04	190 ± 10
30-9-03	160 ± 10	3-2-04	30 ± 10	8-6-04	200 ± 10
7-10-03	130 ± 10	10-2-04	10 ± 10	15-6-04	200 ± 10
14-10-03	150 ± 10	17-2-04	40 ± 10	22-6-04	60 ± 10
21-10-03	200 ± 10	24-2-04	60 ± 10	28-6-04	90 ± 10
28-10-03	120 ± 10	2-3-04	100 ± 10		

Notes:
1. Refer to Figure 2 for the location of this sampling point. The weekly water samples were also combined into monthly composite samples and analysed for gross alpha, gross beta and gamma activity.
2. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 14. TRITIUM IN SURFACE WATER, MDP+60m, LHSTC, July 2003 to June 2004

Date	**Tritium** (Bq/L)	Date	**Tritium** (Bq/L)	Date	**Tritium** (Bq/L)
1-7-03	110 ± 10	3-11-03	80 ± 10	9-3-04	120 ± 10
8-7-03	90 ± 10	11-11-03	150 ± 10	16-3-04	90 ± 10
15-7-03	100 ± 10	18-11-03	300 ± 10	23-3-04	120 ± 10
22-7-03	110 ± 10	25-11-03	60 ± 10	30-3-04	70 ± 10
29-7-03	90 ± 10	2-12-03	110 ± 10	6-4-04	70 ± 10
5-8-03	70 ± 10	9-12-03	50 ± 10	13-4-04	100 ± 10
12-8-03	70 ± 10	17-12-03	90 ± 10	20-4-04	90 ± 10
19-8-03	70 ± 10	23-12-03	60 ± 10	27-4-04	90 ± 10
26-8-03	100 ± 10	30-12-03	30 ± 10	4-5-04	90 ± 10
2-9-03	90 ± 10	6-1-04	50 ± 10	11-5-04	70 ± 10
9-9-03	90 ± 10	13-1-04	30 ± 10	21-5-04	60 ± 10
16-9-03	80 ± 10	20-1-04	30 ± 10	25-5-04	80 ± 10
23-9-03	70 ± 10	28-1-04	40 ± 10	1-6-04	90 ± 10
30-9-03	90 ± 10	3-2-04	50 ± 10	8-6-04	80 ± 10
7-10-03	70 ± 10	10-2-04	30 ± 10	15-6-04	70 ± 10
14-10-03	70 ± 10	17-2-04	50 ± 10	22-6-04	70 ± 10
21-10-03	110 ± 10	24-2-04	60 ± 10	28-6-04	70 ± 10
28-10-03	80 ± 10	2-3-04	80 ± 10		

Notes:
1. Refer to Figure 2 for the location of this sampling point, 60m downstream of MDP Bund C.
2. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 15. TRITIUM IN SURFACE WATER, BARDENS CREEK WEIR, LHSTC, July 2003 to June 2004

Date	**Tritium** (Bq/L)	Date	**Tritium** (Bq/L)	Date	**Tritium** (Bq/L)
1-7-03	50 ± 10	3-11-03	50 ± 10	9-3-04	140 ± 10
8-7-03	40 ± 10	11-11-03	60 ± 10	16-3-04	350 ± 10
15-7-03	30 ± 10	18-11-03	80 ± 10	23-3-04	150 ± 10
22-7-03	30 ± 10	25-11-03	50 ± 10	30-3-04	70 ± 10
29-7-03	30 ± 10	2-12-03	60 ± 10	6-4-04	60 ± 10
5-8-03	40 ± 10	9-12-03	30 ± 10	13-4-04	60 ± 10
12-8-03	30 ± 10	17-12-03	60 ± 10	20-4-04	60 ± 10
19-8-03	40 ± 10	23-12-03	90 ± 10	27-4-04	60 ± 10
26-8-03	30 ± 10	30-12-03	80 ± 10	4-5-04	70 ± 10
2-9-03	30 ± 10	6-1-04	80 ± 10	11-5-04	50 ± 10
9-9-03	20 ± 10	13-1-04	80 ± 10	18-5-04	50 ± 10
16-9-03	30 ± 10	20-1-04	180 ± 10	25-5-04	50 ± 10
23-9-03	10 ± 10	28-1-04	210 ± 10	1-6-04	90 ± 10
30-9-03	30 ± 10	3-2-04	70 ± 10	8-6-04	80 ± 10
7-10-03	60 ± 10	10-2-04	60 ± 10	15-6-04	60 ± 10
14-10-03	70 ± 10	17-2-04	150 ± 10	22-6-04	40 ± 10
21-10-03	80 ± 10	24-2-04	140 ± 10	28-6-04	50 ± 10
28-10-03	50 ± 10	2-3-04	60 ± 10		

Notes:
1. Refer to Figure 2 for the location of this sampling point.
2. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 16. RADIOACTIVITY IN STORMWATER, BUND C MONTHLY COMPOSITES, LHSTC, July 2003 to June 2004

			Gamma-emitters (Bq/L)					
Month	**Gross Alpha** (Bq/L)	**Gross Beta** (Bq/L)	**Am-241**	**Be-7**	**Cs-137**	**Co-60**	**I-131**	**K-40**
July 2003	0.01 ± 0.01	0.16 ± 0.01	< MDA	< MDA	0.008 ± 0.002	< MDA	< MDA	0.070 ± 0.035
August 2003	< MDA	0.18 ± 0.01	< MDA	< MDA	< MDA	< MDA	< MDA	< MDA
September 2003	< MDA	0.27 ± 0.01	< MDA	< MDA	0.028 ± 0.004	< MDA	< MDA	0.112 ± 0.037
October 2003	0.03 ± 0.01	0.38 ± 0.01	< MDA	0.126 ± 0.018	0.014 ± 0.003	< MDA	< MDA	0.103 ± 0.046
November 2003	0.09 ± 0.01	0.38 ± 0.01	< MDA	0.246 ± 0.034	0.021 ± 0.003	< MDA	0.050 ± 0.010	< MDA
December 2003	0.02 ± 0.01	0.19 ± 0.01	< MDA	0.142 ± 0.022	0.020 ± 0.003	< MDA	< MDA	0.100 ± 0.034
January 2004	0.04 ± 0.02	0.39 ± 0.02	< MDA	0.170 ± 0.028	0.007 ± 0.002	< MDA	< MDA	0.098 ± 0.004
February 2004	0.03 ± 0.01	0.12 ± 0.01	< MDA	0.115 ± 0.026	< MDA	< MDA	< MDA	< MDA
March 2004	0.03 ± 0.01	0.25 ± 0.01	< MDA	0.044 ± 0.020	0.019 ± 0.004	< MDA	< MDA	< MDA
April 2004	< MDA	3.33 ± 0.03	< MDA	< MDA	0.551 ± 0.062	0.012 ± 0.004	< MDA	0.102 ± 0.046
May 2004	0.24 ± 0.02	4.42 ± 0.04	< MDA	< MDA	0.636 ± 0.072	0.018 ± 0.007	< MDA	0.292 ± 0.058
June 2004	0.10 ± 0.01	2.08 ± 0.02	< MDA	< MDA	0.225 ± 0.026	< MDA	0.119 ± 0.018	0.162 ± 0.034
			Other Gamma-emitters (Bq/L)					
			Ce-144	**Ru-103**	**Ru-106**	**Zr-95**	**Nb-95**	**Co-57**
April 2004			1.460 ± 0.165	0.188 ± 0.022	1.820 ± 0.210	0.046 ± 0.009	0.074 ± 0.011	0.010 ± 0.002
May 2004			0.673 ± 0.078	0.137 ± 0.017	1.861 ± 0.217	< MDA	0.020 ± 0.007	< MDA
June 2004			0.225 ± 0.028	0.035 ± 0.006	0.776 ± 0.093	< MDA	0.007 ± 0.002	< MDA

Notes:
1. Refer to Figure 2 for the MDP Bund C sampling location. The weekly samples were analysed for tritium then combined to make the monthly composites, reported above.
2. The NSW Regulations (*Prot. Env. Operations Act* 1997) limits for radioactivity in Class C waters are: gross alpha 1.1 Bq/L; gross beta 11.1 Bq/L.
3. The gross beta results include the contribution from K-40 (a natural beta-gamma emitter). Be-7 is also of natural origin.
4. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 17. RADIOACTIVITY IN SURFACE WATER, MDP+60m MONTHLY COMPOSITES, LHSTC, July 2003 to June 2004

			Gamma-emitters (Bq/L)				
Month	**Gross Alpha** (Bq/L)	**Gross Beta** (Bq/L)	**Am-241**	**Be-7**	**Cs-137**	**Co-60**	**K-40**
July 2003	0.02 ± 0.01	0.16 ± 0.01	< MDA	< MDA	0.006 ± 0.002	< MDA	< MDA
August 2003	0.01 ± 0.01	0.17 ± 0.01	< MDA	< MDA	0.007 ± 0.003	< MDA	< MDA
September 2003	0.02 ± 0.01	0.14 ± 0.01	< MDA	< MDA	< MDA	< MDA	< MDA
October 2003	0.03 ± 0.01	0.16 ± 0.01	< MDA	< MDA	0.008 ± 0.003	< MDA	< MDA
November 2003	0.04 ± 0.01	0.26 ± 0.01	< MDA	0.073 ± 0.022	0.017 ± 0.003	< MDA	0.101 ± 0.042
December 2003	0.03 ± 0.01	0.20 ± 0.01	< MDA	< MDA	0.012 ± 0.002	< MDA	0.102 ± 0.028
January 2004	0.06 ± 0.02	0.48 ± 0.02	< MDA	< MDA	0.077 ± 0.022	< MDA	< MDA
February 2004	0.03 ± 0.01	0.11 ± 0.01	< MDA	0.066 ± 0.022	0.012 ± 0.003	< MDA	< MDA
March 2004	< MDA	0.35 ± 0.01	< MDA	< MDA	0.014 ± 0.003	< MDA	< MDA
April 2004	0.05 ± 0.01	0.70 ± 0.01	< MDA	< MDA	0.080 ± 0.010	< MDA	< MDA
May 2004	0.04 ± 0.01	0.37 ± 0.01	< MDA	< MDA	< MDA	< MDA	< MDA
June 2004	0.02 ± 0.01	0.25 ± 0.01	< MDA	< MDA	0.026 ± 0.004	< MDA	< MDA

	Other Gamma-emitters (Bq/L)		
	Ce-144	**Ru-103**	**Ru-106**
April 2004	< MDA	0.019 ± 0.004	0.194 ± 0.039

Notes:
1. Refer to Figure 2 for the location of this sampling point, 60m downstream of the MDP Bund. The weekly samples were analysed for tritium, then combined to make the monthly composites, reported above.
2. The NSW Regulations (*Prot. Env. Operations Act* 1997) limits for radioactivity in Class C waters are: gross alpha 1.1 Bq/L; gross beta 11.1 Bq/L.
3. The gross beta results include the contribution from K-40 (a natural beta-gamma emitter). Be-7 is also of natural origin.
4. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 18. RADIOACTIVITY IN SURFACE WATER, SPCC SAMPLING POINTS, LHSTC, July 2003 to June 2004

	Strassman Creek		Bardens Creek Weir		MDP Creek	
Date Sampled	**Gross Alpha** (Bq/L)	**Gross Beta** (Bq/L)	**Gross Alpha** (Bq/L)	**Gross Beta** (Bq/L)	**Gross Alpha** (Bq/L)	**Gross Beta** (Bq/L)
14-7-03	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.06 ± 0.01	0.02 ± 0.01	0.13 ± 0.01
1-8-03	0.02 ± 0.01	0.02 ± 0.01	< MDA	0.02 ± 0.01	0.01 ± 0.01	0.14 ± 0.01
3-9-03	< MDA	0.03 ± 0.01	< MDA	0.02 ± 0.01	< MDA	0.15 ± 0.01
27-10-03	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.11 ± 0.01
20-11-03	0.01 ± 0.01	0.02 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.12 ± 0.01
31-12-03	< MDA	0.03 ± 0.01	< MDA	0.01 ± 0.01	< MDA	0.15 ± 0.01
30-1-04	0.01 ± 0.01	0.04 ± 0.01	0.02 ± 0.01	0.05 ± 0.01	0.01 ± 0.01	0.13 ± 0.01
26-2-04	0.03 ± 0.01	0.04 ± 0.01	0.02 ± 0.01	0.04 ± 0.01	0.01 ± 0.01	0.15 ± 0.01
23-3-04	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.01 ± 0.01	0.12 ± 0.01
27-4-04	0.01 ± 0.01	0.04 ± 0.01	0.01 ± 0.01	0.05 ± 0.01	0.01 ± 0.01	0.20 ± 0.01
15-5-04	0.01 ± 0.01	0.04 ± 0.01	< MDA	0.05 ± 0.01	0.01 ± 0.01	0.22 ± 0.01
28-5-04	0.01 ± 0.01	0.04 ± 0.01	0.01 ± 0.01	0.07 ± 0.01	0.02 ± 0.01	0.17 ± 0.01
16-6-04	0.01 ± 0.01	0.04 ± 0.01	0.01 ± 0.01	0.05 ± 0.01	0.02 ± 0.01	0.18 ± 0.01

Notes:
1. See Figure 2 for the location of the SPCC sampling points.
2. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.
3. All gross beta results include the beta activity due to natural K-40.
4. The NSW Regulations (*Prot. Env. Operations Act* 1997) limits for radioactivity in Class C waters are gross alpha: 1.1 Bq/L; gross beta: 11.1 Bq/L.

Table 19. RADIOACTIVITY IN CREEKS NORTH OF THE LFBG, July 2003 to June 2004

WATER (Bq/L)

Sample Location	Date Sampled	Gross Alpha	Gross Beta	Gamma-emitters				Tritium
				Am-241	Cs-137	Co-60	K-40	
Mill Creek	12-11-03	0.03 ± 0.01	0.13 ± 0.01	< MDA	< MDA	< MDA	< MDA	< MDA
Bardens Creek	12-11-03	0.02 ± 0.01	0.17 ± 0.01	< MDA	< MDA	< MDA	< MDA	< MDA

SEDIMENT (Bq/g DW)

Sample Location	Date Sampled	Gross Alpha	Gross Beta	Gamma-emitters				Be-7
				Am-241	Cs-137	Co-60	K-40	
Mill Creek	12-11-03	1.18 ± 0.13	0.23 ± 0.02	< MDA	< MDA	< MDA	0.117 ± 0.014	< MDA
Bardens Creek	12-11-03	0.83 ± 0.12	0.09 ± 0.02	< MDA	< MDA	< MDA	0.080 ± 0.010	< MDA

Notes:
1. See Figure 1 for the location of these sampling points.
2. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 20. TRITIUM IN WATERS, WORONORA RIVER ESTUARY AND FORBES CREEK, July 2003 to June 2004

	Tritium (Bq/L)	
	Woronora Estuary	
Date Sampled	**Station E5.9**	**Forbes Creek**
3-7-03	< MDA	< MDA
1-8-03	< MDA	< MDA
3-9-03	20 ± 10	< MDA
20-10-03	< MDA	< MDA
11-11-03	< MDA	< MDA
19-12-03	< MDA	< MDA
21-1-04	< MDA	< MDA
26-2-04	< MDA	< MDA
12-3-04	< MDA	< MDA
27-4-04	< MDA	< MDA
18-5-04	< MDA	< MDA
28-6-04	< MDA	< MDA

Notes:
1. Figure 1 shows the sampling locations.
2. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 21. RADIOACTIVITY IN GROUNDWATER FROM THE VICINITY OF BUILDING 27, July 2003 to June 2004

	Gamma-emitters (Bq/L)				**Tritium**
Date Sampled	**Am-241**	**Cs-137**	**Co-60**	**K-40**	Bq/L
31-7-03	< MDA	< MDA	< MDA	< MDA	490 ± 20
29-8-03	< MDA	< MDA	< MDA	< MDA	500 ± 20
30-9-03	< MDA	< MDA	< MDA	< MDA	500 ± 20
30-10-03	< MDA	< MDA	< MDA	< MDA	410 ± 20
1-12-03	< MDA	< MDA	< MDA	< MDA	440 ± 20
31-12-03	< MDA	< MDA	< MDA	< MDA	470 ± 20
28-1-04	< MDA	< MDA	< MDA	< MDA	480 ± 20
26-2-04	< MDA	< MDA	< MDA	< MDA	420 ± 20
12-3-04	< MDA	< MDA	< MDA	< MDA	430 ± 20
12-5-04	< MDA	< MDA	< MDA	< MDA	550 ± 20

Notes:
1. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.
2. The sample collection for April was delayed until 12 May, to allow for the removal of tree roots which were blocking the inlet to the sampling point.
3. The sump was used for operational purposes from late May, hence further sampling was suspended.

Table 22. FIELD PARAMETERS IN GROUNDWATER, LHSTC, August 2003

Piezometer	Sampling Depth (mBTOC)	SWL (mBTOC)	Temperature (°C)	EC (µS/cm)	pH	Eh (mV)	Turbidity (NTU)
MW1S	12	7.77	17.5	181	4.7	250	330
MW1D	15	8.13	17.9	494	3.8	440	10
MW2S	9	1.68	15.1	192	4.7	300	220
MW2D	20	2.75	16.4	298	5.0	190	70
MW3S	ND	1.70	17.5	311	5.3	240	110
MW3D	20	3.30	16.0	279	4.0	350	330
MW4S	6	1.49	14.5	1028	6.4	-30	330
MW4D	ND	3.59	17.3	241	4.5	260	40
MW5S	8	2.37	19.4	230	4.7	260	330
MW6S	9	3.82	16.7	270	5.7	210	330
MW6D	20	10.99	18.1	411	5.3	230	90
MW7S	5	2.45	15.9	377	4.4	190	330
MW7D	ND	12.86	17.2	524	3.6	440	330
MW8S	-	-	-	-	-	-	-
MW8D	28	22.64	18.0	154	5.4	170	130
MW9S	17	10.09	17.2	348	3.9	420	330
MW9D	20	11.87	17.3	378	4.3	370	40
MW10S	12	4.76	17.2	228	4.3	310	90
MW11-2	13	9.04	19.9	391	4.8	270	40
MW13	21	14.92	20.0	287	4.9	280	40
MW 14	22	12.90	19.1	407	4.8	200	90
MW15S	12	3.62	17.5	310	4.2	380	150
MW15D	15	3.95	17.7	284	4.9	300	20
BH3	22	15.16	19.0	336	5.4	210	100
BH3A	13	10.65	19.4	367	4.7	230	150
BH6	15	10.40	19.1	374	4.0	350	200
BH112	25	17.14	19.1	456	4.4	230	160

Notes:
1. Field parameters were measured five times (the average reading is given) using a flowcell and a calibrated water quality analyser probe.
2. MW8S not sampled as piezometer was dry.
3. SWL - Standing water level.
4. mBTOC - metres below the top of the piezometer casing.
5. ND - not determined.
6. EC - electrical conductivity, measured in micro Siemens per centimetre.
7. Eh - oxidation/reduction potential measured in millivolts.
8. NTU - Nephelometric Turbidity Units.

Table 23. FIELD PARAMETERS IN GROUNDWATER, LHSTC, December 2003

Piezometer	Sampling Depth (mBTOC)	SWL (mBTOC)	Temperature (°C)	EC (µS/cm)	pH	Eh (mV)	Turbidity (NTU)
MW1S	11	8.22	18.9	219	4.9	30	590
MW1D	20	8.54	18.8	375	4.0	320	70
MW2S	5	3.30	18.8	225	4.7	290	190
MW2D	10	3.08	17.7	326	5.0	220	130
MW3S	5	2.07	20.2	296	4.0	340	390
MW3D	10	2.00	18.4	362	5.5	120	80
MW4S	4	1.50	19.9	979	6.4	-60	170
MW4D	10	3.79	18.4	298	5.4	120	40
MW5S	6	2.28	22.8	139	5.1	220	150
MW6S	6	3.65	20.3	238	6.3	220	90
MW6D	14	14.05	19.1	309	5.6	230	40
MW7S	5	3.47	21.0	250	4.6	200	120
MW7D	15	13.28	21.2	550	3.7	470	30
MW8S	-	-	-	-	-	-	-
MW8D	23	22.80	19.3	146	5.4	210	40
MW9S	16	10.82	19.0	289	4.3	370	330
MW9D	26	12.35	18.5	329	4.3	390	100
MW10S	9	2.96	18.8	256	4.4	310	90
MW11-2	15	9.30	21.6	394	4.6	290	40
MW13	20	15.07	23.1	259	4.4	310	20
MW 14	24	13.47	21.8	412	5.0	160	190
MW15S	5	3.33	19.6	331	5.0	250	50
MW15D	5	3.35	19.4	275	4.6	330	40
BH3	22	14.67	19.8	241	6.4	170	200
BH3A	12	10.57	21.1	304	4.7	250	260
BH6	13	10.41	21.2	293	5.1	320	250
BH112	25	20.70	20.4	401	5.1	180	240

Notes:
1. Field parameters were measured five times (the average reading is given) using a flowcell and a calibrated water quality analyser probe.
2. MW8S not sampled as piezometer was dry.
3. SWL - Standing water level.
4. mBTOC - metres below the top of the piezometer casing.
5. ND - not determined.
6. EC - electrical conductivity, measured in micro Siemens per centimetre.
7. Eh - oxidation/reduction potential measured in millivolts.
8. NTU - Nephelometric Turbidity Units.

Table 24. FIELD PARAMETERS IN GROUNDWATER, LHSTC, March 2004

Piezometer	Sampling Depth (mBTOC)	SWL (mBTOC)	Temperature (°C)	EC (µS/cm)	pH	Eh (mV)	Turbidity (NTU)
MW1S	ND	8.44	19.8	222	4.6	50	420
MW1D	12	8.77	19.2	343	4.0	310	20
MW2S	7	3.36	19.8	182	4.7	220	290
MW2D	10	4.82	18.7	304	5.6	60	50
MW3S	6	2.18	20.9	269	4.1	280	600
MW3D	16	11.06	18.7	358	5.8	20	70
MW4S	5	1.52	21.3	1010	6.4	-70	190
MW4D	8	3.93	19.9	241	5.4	80	40
MW5S	7	3.29	22.3	145	4.9	150	310
MW6S	7	3.43	21.8	249	6.7	110	190
MW6D	24	17.10	20.0	272	5.7	150	250
MW7S	ND	4.44	26.6	274	5.2	-40	600
MW7D	20	13.55	22.4	440	4.1	330	460
MW8S	-	-	-	-	-	-	-
MW8D	27	22.93	19.1	138	5.0	210	90
MW9S	14	11.10	19.4	186	4.6	220	20
MW9D	16	12.82	20.3	189	4.9	160	10
MW10S	11	4.94	19.7	157	6.2	40	170
MW11-2	15	9.35	21.7	309	4.7	260	40
MW13	ND	15.05	29.0	152	8.2	90	50
MW 14	20	13.38	19.6	330	4.7	210	150
MW15S	-	-	-	-	-	-	-
MW15D	-	-	-	-	-	-	-
BH3	21	15.91	19.1	146	6.4	90	80
BH3A	-	-	-	-	-	-	-
BH6	16	11.21	19.3	289	7.6	-60	600
BH112	26	21.07	21.1	325	5.4	80	400

Notes:
1. Field parameters were measured five times (the average reading is given) using a flowcell and a calibrated water quality analyser probe.
2. MW8S and BH3A were not sampled as piezometers were dry. MW15S and MW15D were inaccessible due to RRR construction.
3. SWL - Standing water level.
4. mBTOC - metres below the top of the piezometer casing.
5. ND - not determined.
6. EC - electrical conductivity, measured in micro Siemens per centimetre.
7. Eh - oxidation/reduction potential measured in millivolts.
8. NTU - Nephelometric Turbidity Units.

Table 25. FIELD PARAMETERS IN GROUNDWATER, LHSTC, May 2004

Piezometer	Sampling Depth (mBTOC)	SWL (mBTOC)	Temperature (°C)	EC (µS/cm)	pH	Eh (mV)	Turbidity (NTU)
MW1S	11	8.34	18.8	265	4.5	330	120
MW1D	12	8.57	18.5	390	4.1	320	< 10
MW2S	6	3.28	18.5	205	4.7	210	30
MW2D	14	6.18	17.9	324	5.2	180	30
MW3S	5	2.12	19.1	303	4.1	220	60
MW3D	14	11.06	18.6	389	5.7	110	70
MW4S	5	2.13	18.3	950	6.4	40	140
MW4D	10	4.00	18.9	270	5.4	140	60
MW5S	6	3.48	22.2	227	4.6	210	30
MW6S	7	3.88	19.4	195	5.9	200	40
MW6D	9	6.95	19.3	361	5.7	150	190
MW7S	ND	4.55	19.1	266	4.9	-10	550
MW7D	17	13.31	18.7	244	7.2	60	40
MW8S	-	-	-	-	-	-	-
MW8D	23	23.20	18.5	162	5.0	250	260
MW9S	14	10.80	17.1	286	4.5	340	20
MW9D	17	13.19	18.1	391	5.0	280	110
MW10S	6	3.51	19.5	285	6.4	80	140
MW11-2	14	9.55	18.5	361	4.9	300	40
MW13	20	15.10	19.0	317	4.5	210	30
MW 14	20	13.37	19.1	408	5.2	190	100
MW15S	6	3.01	19.2	337	4.8	210	20
MW15D	12	7.71	18.5	268	5.3	190	< 10
BH3	17	15.61	18.6	211	6.1	280	50
BH3A	13	10.37	18.6	349	5.0	290	30
BH6	14	10.01	18.1	391	5.0	280	110
BH112	24	17.79	18.3	382	4.5	290	150

Notes:
1. Field parameters were measured five times (the average reading is given) using a flowcell and a calibrated water quality analyser probe.
2. MW8S not sampled as piezometer was dry.
3. SWL - Standing water level.
4. mBTOC - metres below the top of the piezometer casing.
5. ND - not determined.
6. EC - electrical conductivity, measured in micro Siemens per centimetre.
7. Eh - oxidation/reduction potential measured in millivolts.
8. NTU - Nephelometric Turbidity Units.

Table 26. MAJOR IONS IN GROUNDWATER, LHSTC, August 2003

Piezometer	Na (mg/L)	K (mg/L)	Mg (mg/L)	Ca (mg/L)	Cl (mg/L)	SO_4 (mg/L)	HCO_3 (mg/L)
MW1S	25.2	4.76	3.35	0.26	42	13	<0.1
MW1D	67.6	0.53	6.32	0.73	150	14	<0.1
MW2S	21.4	3.69	6.69	0.75	50	9	<0.1
MW2D	37.9	2.14	6.26	2.68	78	16	5.8
MW3S	35.1	2.68	3.99	0.46	71	21	<0.1
MW3D	38.1	1.77	8.07	3.87	81	11	22.6
MW4S	41.6	5.48	26.8	151	69	<0.1	298
MW4D	30.2	1.13	4.91	1.16	54	10	<0.1
MW5S	19.8	6.56	2.40	1.35	19	32	<0.1
MW6S	10.7	5.34	2.67	22.3	15	30	40.4
MW6D	44.7	1.78	6.29	8.38	84	13	29.9
MW7S	48.0	7.69	8.83	4.89	64	87	<0.1
MW7D	61.5	4.07	9.16	1.22	150	32	<0.1
MW8S	-	-	-	-	-	-	-
MW8D	13.4	4.98	1.75	6.77	21	13	3.1
MW9S	34.7	5.27	3.84	1.52	70	14	<0.1
MW9D	35.6	0.86	4.50	3.49	76	12	1.0
MW10S	33.5	3.17	2.45	1.04	51	19	<0.1
MW11-2	50.2	1.88	5.86	2.02	80	26	7.6
MW13	26.3	1.37	4.43	8.84	37	43	7.8
MW 14	49.3	2.52	7.04	5.24	75	48	8.2
MW15S	39.0	2.61	4.42	1.87	83	18	<0.1
MW15D	34.2	1.93	4.03	1.71	50	33	4.3
BH3	29.3	4.79	3.64	6.37	60	13	14.4
BH3A	41.4	1.25	3.89	2.52	79	16	<0.1
BH6	39.9	2.94	6.41	5.79	27	91	<0.1
BH112	42.5	3.22	7.66	4.03	100	20	<0.1

Notes:
1. Concentrations quoted are for dissolved ions.
2. MW8S not sampled as piezometer was dry.

Table 27. RADIOACTIVITY IN GROUNDWATER, LHSTC, August 2003

		RADIOACTIVITY (Bq/L)						
				Gamma-emitters				
Piezometer	**Date Sampled**	**Gross Alpha**	**Gross Beta**	**Am-241**	**Cs-137**	**Co-60**	**K-40**	**Tritium**
MW1S	11-08-03	0.05 ± 0.01	0.07 ± 0.01	< MDA	< MDA	< MDA	0.295 ± 0.136	20.2 ± 0.4
MW1D	11-08-03	0.20 ± 0.02	0.18 ± 0.01	< MDA	< MDA	< MDA	< MDA	11.6 ± 0.4
MW2S	8-08-03	0.01 ± 0.01	0.01 ± 0.01	< MDA	< MDA	< MDA	< MDA	111.2 ± 0.6
MW2D	8-08-03	0.02 ± 0.01	0.02 ± 0.01	< MDA	< MDA	< MDA	< MDA	< MDA
MW3S	8-08-03	0.14 ± 0.01	0.14 ± 0.01	< MDA	< MDA	< MDA	0.668 ± 0.133	30.1 ± 0.4
MW3D	8-08-03	0.01 ± 0.01	0.04 ± 0.01	< MDA	< MDA	< MDA	0.240 ± 0.110	2.4 ± 0.4
MW4S	8-08-03	0.04 ± 0.02	0.09 ± 0.01	< MDA	< MDA	< MDA	< MDA	3.3 ± 0.4
MW4D	8-08-03	0.04 ± 0.01	0.03 ± 0.01	< MDA	< MDA	< MDA	< MDA	< MDA
MW5S	8-08-03	0.03 ± 0.01	0.02 ± 0.01	< MDA	< MDA	< MDA	< MDA	88.1 ± 0.5
MW6S	11-08-03	0.02 ± 0.01	0.11 ± 0.01	< MDA	< MDA	< MDA	< MDA	124.2 ± 0.6
MW6D	11-08-03	0.02 ± 0.01	0.03 ± 0.01	< MDA	< MDA	< MDA	< MDA	7.1 ± 0.4
MW7S	8-08-03	0.06 ± 0.01	0.06 ± 0.01	< MDA	< MDA	< MDA	0.228 ± 0.107	45.3 ± 0.4
MW7D	8-08-03	0.22 ± 0.02	0.20 ± 0.01	< MDA	< MDA	< MDA	< MDA	4.4 ± 0.4
MW8S	-	-	-	-	-	-	-	-
MW8D	8-08-03	0.01 ± 0.01	0.02 ± 0.01	< MDA	< MDA	< MDA	< MDA	2.1 ± 0.4
MW9S	11-08-03	0.07 ± 0.01	0.03 ± 0.01	< MDA	< MDA	< MDA	< MDA	13.6 ± 0.4
MW9D	11-08-03	0.03 ± 0.01	0.02 ± 0.01	< MDA	< MDA	< MDA	< MDA	5.6 ± 0.4
MW10S	11-08-03	0.12 ± 0.01	0.07 ± 0.01	< MDA	< MDA	< MDA	< MDA	41.6 ± 0.4
MW11-2	12-08-03	0.03 ± 0.01	0.04 ± 0.01	< MDA	< MDA	< MDA	< MDA	16.3 ± 0.4
MW13	12-08-03	0.09 ± 0.01	0.05 ± 0.01	< MDA	< MDA	< MDA	< MDA	8.6 ± 0.4
MW 14	12-08-03	0.02 ± 0.01	0.03 ± 0.01	< MDA	< MDA	< MDA	0.397 ± 0.120	98.5 ± 0.5
MW15S	11-08-03	0.13 ± 0.01	0.09 ± 0.01	< MDA	< MDA	< MDA	< MDA	4.0 ± 0.4
MW15D	11-08-03	0.07 ± 0.01	0.05 ± 0.01	< MDA	< MDA	< MDA	< MDA	23.0 ± 0.4
BH3	12-08-03	0.05 ± 0.01	0.09 ± 0.01	< MDA	< MDA	< MDA	0.274 ± 0.105	4.2 ± 0.4
BH3A	12-08-03	0.06 ± 0.01	0.05 ± 0.01	< MDA	< MDA	< MDA	< MDA	18.3 ± 0.4
BH6	12-08-03	0.06 ± 0.01	0.07 ± 0.01	< MDA	< MDA	< MDA	< MDA	41.7 ± 0.4
BH112	12-08-03	0.07 ± 0.01	0.08 ± 0.01	< MDA	< MDA	< MDA	< MDA	7.3 ± 0.4

Notes:
1. Gross beta activity includes any contribution from natural K-40. Tritium analyses performed in low-level facility.
2. MW8S not sampled as piezometer was dry.
3. < MDA indicates that the result was below the minimal detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 28. RAINFALL AND POTENTIAL EVAPORATION DATA FROM LHSTC, January 1993 to June 2004

		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Jan.	R Total	50.2	11.2	122.1	136	113.2	75	111.9	29.6	191	55.2	22.5	38.9
	R Days	10	7	12	13	11	11	14	12	9	10	6	8
	E Total	149	205.2	135.8	125.2	151.8	163.9	165.4	138	151.3	176.6	173.2	163.9
	E Max	9.1	12.6	7.9	7.6	7.8	10.1	10	8	10.1	13.4	11.0	9.2
Feb.	R Total	88.5	47.3	47.6	64.1	127.7	56	196.5	11	110.6	295.1	89.1	92.5
	R Days	11	8	12	15	10	8	14	9	11	18	12	9
	E Total	133.4	147.6	122.9	137.5	118.5	154.7	113.1	149.6	108.4	103.4	118.2	138.6
	E Max	8	10.2	7.6	7.8	11.3	10	6.6	9.3	6.4	8.7	8.0	7.8
Mar.	R Total	144.6	151.7	205.4	33.7	61.2	15.5	40.2	217.6	122	143.3	89.0	52.8
	R Days	17	17	16	9	10	8	10	14	20	15	8	5
	E Total	117.0?	118.3?	123.7	101.7	124	127.8	94.3	94.6	110.1	90.2	118.1	109.3
	E Max	10.4?	8.2?	8.4	6.1	6.2	7.7	5.1	5.1	7.9	5.5	8.5	7.5
April	R Total	30.3	95.5	14.2	33.2	0.5	161.3	94.3	31.9	70.2	15.4	147.2	107.4
	R Days	7	8	2	6	1	10	17	12	7	6	16	7
	E Total	83	85.9	91	99.2	91.9	94.9	72	65.3	78	68.8	69.0	73.4
	E Max	4.5	5.8	5.5	6.4	7	8.1	4	4	5	3.5	4.9	5.6
May	R Total	15.8	25.5	199.9	143.5	96.5	203.7	48.7	34.5	105.3	50.6	358.8	9.2
	R Days	4	5	16	14	16	13	10	9	10	11	17	1
	E Total	55.3	82	67.7	60.1	64.7	61.8	44.7	54.9	58.1	61.6	71.7	69.8
	E Max	4.9	6.6	6	3.9	4.7	4.9	3.4	3.4	4.5	3.7	6.8	3.8
June	R Total	34.3	39.5	40.4	51.8	51	80.2	66.6	34.2	9.3	18.1	58.0	5.4
	R Days	6	7	8	9	10	11	14	9	6	5	7	3
	E Total	53.3	51.1	44.1	58.9	54.7	45.5	45.9	45.7	44.4	49.1	49.3	58.4
	E Max	3.4	3.5	3.3	3.8	6.4	4.1	2.8	4.5	2.4	3.1	3.5	3.7
July	R Total	64.8	7.4	1	78.4	48.2	86.8	163.3	31.4	109.2	26.4	35.5	
	R Days	10	8	4	6	6	12	12	9	14	2	8	
	E Total	42.1	56.7	52.7	60	52.7	50.1	47.4	52.1	44.3	57	49.7	
	E Max	2.6	3.1	3.5	3.2	2.6	3.8	4.1	3.8	2.3	3.3	3.8	
Aug.	R Total	69	8.4	0	129.9	18.7	316.3	31.2	19.2	49.4	14.3	30.0	
	R Days	9	2	0	6	5	15	8	11	6	7	7	
	E Total	76.6	85.5	86.1	76	82.4	51	65.6	59.6	75.4	73	75.4	
	E Max	6.6	6	5.2	5	6.9	3.3	3.2	4.3	5.5	5.9	5.8	
Sept.	R Total	81.8	10.4	249.3	74.8	105.6	37.7	20.7	37.2	18.2	7	4.4	
	R Days	10	2	13	7	15	9	5	6	10	4	2	
	E Total	89.4	130.8	85.8	120	78.7	82.5	82.5	120.6	82.9	118.4	113.8	
	E Max	5	6.6	7	7.5	6	5.5	4.4	7.5	5	8.5	6.8	
Oct.	R Total	54.6	35.1	34.4	31.2	60.2	26.7	211	55.1	39.8	1.4	62.4	
	R Days	7	9	10	10	8	8	13	9	8	4	13	
	E Total	138.2	139	121.9	118.1	136.9	121.1	104.1	117.2	128.9	149.8	102.5	
	E Max	9.9	7.2	6.6	6.8	7.6	6.8	6.3	6.8	7.6	8.5	6.6	
Nov.	R Total	57.3	94.2	135.4	70.8	21.7	110.3	32.7	150.3	57.1	14.5	50.0	
	R Days	9	14	15	12	9	15	9	17	11	6	10	
	E Total	142.4?	164.6	126.4	146.5	150.2	113.6	112.1	100.5	129.6	157.1	133.2	
	E Max	13.6?	10.5	7.2	7.3	7.5	7.2	5.4	6	9.4	10.3	7.0	
Dec.	R Total	40.7	50.7	93.9	68.8	27.3	37.8	112.8	46.4	15.9	59.8	45.9	
	R Days	12	9	13	6	7	9	13	11	8	9	8	
	E Total	167.3	163.7	155	160.6	162.9	148.9	140.4	170.5	150.5	177.2	142.9	
	E Max	8.8	11.6	8.5	8.2	11.2	9.6	6.8	10.1	10.8	12.7	9	
Annual	**R Total**	**731.9**	**576.2**	**1143.6**	**916.2**	**731.8**	**695.8**	**1129.9**	**698.4**	**898**	**701.1**	**992.8**	
	R Days	**112**	**87**	**121**	**113**	**108**	**129**	**139**	**128**	**120**	**97**	**114**	
	E Total	**1247**	**1430.4**	**1220.4**	**1260.5**	**1269.4**	**1215.8**	**1087.5**	**1168.6**	**1161.9**	**1282.2**	**1217.0**	

Notes: Rainfall (R) and potential Evaporation (E) are measured in millimetres. Data labelled with ? denotes uncertainty in evaporation measurement.

Table 29. FIELD PARAMETERS IN GROUNDWATER, LFBG, November 2003

Piezometer	Sampling Depth (mBTOC)	SWL (mBTOC)	Temperature (°C)	EC (µS/cm)	pH	Eh (mV)	Turbidity (NTU)
MB11	6	3.78	19.8	354	5.7	160	70
MB12	4	2.91	18.2	566	5.5	320	80
MB13	5	1.91	17.7	386	5.5	230	550
MB14	5	3.37	18.5	845	6.2	-10	390
MB15	6	4.20	19.6	402	5.7	380	600
MB16	5	2.41	18.0	295	5.6	160	370
MB17	4	1.87	19.4	423	5.5	250	600
MB18	5	3.75	20.0	1213	6.3	80	150
MB19	5	2.82	15.5	3493	6.3	60	210
MB20	5	2.40	15.0	722	6.6	-20	260
MB21	4	2.07	15.6	2076	6.3	100	600
BH10	5	1.61	18.3	1773	5.5	180	160
BHF	9	2.50	18.0	728	5.3	170	150
OS2	2	1.90	17.4	194	6.8	120	600
OS3	3	1.65	19.4	307	5.3	190	280
P1S	5	2.98	18.2	3098	4.5	340	600
P1D	10	3.30	18.3	7697	5.5	100	80
P2D	20	12.48	17.8	5711	6.0	40	50
CW	10	4.20	19.2	2153	5.8	250	430

Notes:
1. SWL - Standing water level.
2. mBTOC - metres below the top of the piezometer casing.
3. Field parameters were measured five times (the average reading is given) using a flowcell and a calibrated water quality analyser probe.
4. EC - electrical conductivity, measured in micro Siemens per centimetre.
5. Eh - oxidation/reduction potential measured in millivolts.
6. NTU - Nephelometric Turbidity Units.

Table 30. FIELD PARAMETERS IN GROUNDWATER, LFBG, April 2004

Piezometer	Sampling Depth (mBTOC)	SWL (mBTOC)	Temperature (°C)	EC (µS/cm)	pH	Eh (mV)	Turbidity (NTU)
MB11	6	4.13	19.7	444	5.6	410	80
MB12	5	3.86	21.6	789	5.4	340	30
MB13	6	2.33	20.7	341	5.4	290	470
MB14	6	3.89	19.0	1955	6.0	120	90
MB15	7	4.61	19.8	789	5.9	310	240
MB16	6	3.10	20.2	284	5.5	210	190
MB17	5	2.58	20.7	444	5.6	290	80
MB18	7	4.12	19.7	1381	6.5	150	390
MB19	6	3.64	17.6	4151	6.2	90	60
MB20	5	3.49	17.6	733	6.5	-30	110
MB21	4	2.64	18.8	1811	6.4	90	220
BH10	5	2.19	19.1	1693	5.6	130	50
BHF	10	3.16	18.7	1083	5.3	320	90
OS2	-	-	-	-	-	-	-
OS3	4	2.20	21.9	219	5.3	410	250
P1S	6	3.77	20.4	3493	4.1	560	500
P1D	12	4.04	18.5	8000	5.6	170	120
P2D	28	13.37	18.5	5490	6.1	50	120
CW	8	4.49	19.5	2033	6.0	270	230

Notes:
1. SWL - Standing water level.
2. mBTOC - metres below the top of the piezometer casing.
3. Field parameters were measured five times (the average reading is given) using a flowcell and a calibrated water quality analyser probe.
4. EC - electrical conductivity, measured in micro Siemens per centimetre.
5. Eh - oxidation/reduction potential measured in millivolts.
6. NTU - Nephelometric Turbidity Units.
7. OS2 was not sampled as piezometer was dry.

Table 31. RADIOACTIVITY IN GROUNDWATER, LFBG, November 2003

		RADIOACTIVITY (Bq/L)						
				Gamma-emitters				
Piezometer	**Date Sampled**	**Gross Alpha**	**Gross Beta**	**Am-241**	**Cs-137**	**Co-60**	**K-40**	**Tritium**
MB11	21-Nov-03	0.01 ± 0.01	0.07 ± 0.01	< MDA	< MDA	< MDA	0.631 ± 0.153	10 ± 10
MB12	21-Nov-03	0.02 ± 0.01	0.08 ± 0.01	< MDA	< MDA	< MDA	< MDA	10 ± 10
MB13	21-Nov-03	0.12 ± 0.02	0.17 ± 0.01	< MDA	< MDA	< MDA	< MDA	2320 ± 30
MB14	21-Nov-03	0.02 ± 0.01	0.12 ± 0.02	< MDA	< MDA	< MDA	< MDA	20 ± 10
MB15	21-Nov-03	0.03 ± 0.01	0.12 ± 0.01	< MDA	< MDA	< MDA	< MDA	10 ± 10
MB16	21-Nov-03	0.23 ± 0.02	0.39 ± 0.01	< MDA	< MDA	0.105 ± 0.018	< MDA	4170 ± 50
MB17	21-Nov-03	0.11 ± 0.02	0.06 ± 0.01	< MDA	< MDA	< MDA	0.446 ± 0.131	730 ± 20
MB18	21-Nov-03	< MDA	0.07 ± 0.02	< MDA	< MDA	< MDA	< MDA	260 ± 10
MB19	24-Nov-03	0.18 ± 0.07	0.31 ± 0.04	< MDA	< MDA	< MDA	0.551 ± 0.141	200 ± 10
MB20	24-Nov-03	0.07 ± 0.02	0.28 ± 0.02	< MDA	< MDA	< MDA	< MDA	10 ± 10
MB21	24-Nov-03	0.12 ± 0.04	0.24 ± 0.02	< MDA	< MDA	< MDA	< MDA	200 ± 10
BH10	21-Nov-03	< MDA	0.12 ± 0.02	< MDA	< MDA	< MDA	0.262 ± 0.122	7290 ± 60
BHF	21-Nov-03	0.05 ± 0.02	0.14 ± 0.01	< MDA	< MDA	< MDA	< MDA	310 ± 10
OS2	24-Nov-03	0.18 ± 0.02	0.16 ± 0.01	< MDA	< MDA	< MDA	< MDA	590 ± 20
OS3	21-Nov-03	0.03 ± 0.02	0.20 ± 0.01	< MDA	< MDA	< MDA	< MDA	1400 ± 30
CW	21-Nov-03	< MDA	0.01 ± 0.01	< MDA	< MDA	< MDA	0.362 ± 0.134	1110 ± 20
P1S	21-Nov-03	0.30 ± 0.08	0.21 ± 0.04	< MDA	< MDA	< MDA	0.591 ± 0.160	10 ± 10
P1D	21-Nov-03	< MDA	< MDA	< MDA	< MDA	< MDA	0.234 ± 0.115	180 ± 10
P2D	24-Nov-03	< MDA	0.34 ± 0.07	< MDA	< MDA	< MDA	0.334 ± 0.136	100 ± 10

Notes:
1. See Figure 4 for the location of the sampling piezometers.
2. Gross beta results include the contribution from natural K-40.
3. < MDA indicates that the result was below the minimal detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 32. RADIOACTIVITY IN GROUNDWATER, LFBG, April 2004

		RADIOACTIVITY (Bq/L)						
				Gamma-emitters				
Piezometer	**Date Sampled**	**Gross Alpha**	**Gross Beta**	**Am-241**	**Cs-137**	**Co-60**	**K-40**	**Tritium**
MB11	15-04-04	0.29 ± 0.11	0.28 ± 0.06	< MDA	< MDA	< MDA	0.360 ± 0.095	10 ± 10
MB12	15-04-04	< MDA	0.05 ± 0.01	< MDA	< MDA	< MDA	< MDA	10 ± 10
MB13	15-04-04	0.02 ± 0.01	0.05 ± 0.01	< MDA	< MDA	< MDA	< MDA	1500 ± 30
MB14	15-04-04	< MDA	0.16 ± 0.02	< MDA	< MDA	< MDA	< MDA	50 ± 10
MB15	15-04-04	0.04 ± 0.02	0.09 ± 0.01	< MDA	< MDA	0.021 ± 0.012	< MDA	60 ± 10
MB16	15-04-04	0.19 ± 0.02	0.36 ± 0.01	< MDA	< MDA	0.105 ± 0.021	< MDA	5870 ± 50
MB17	15-04-04	0.04 ± 0.01	0.08 ± 0.01	< MDA	< MDA	0.020 ± 0.011	< MDA	920 ± 20
MB18	15-04-04	< MDA	0.11 ± 0.02	< MDA	< MDA	< MDA	0.577 ± 0.121	920 ± 20
MB19	16-04-04	0.16 ± 0.07	0.55 ± 0.07	< MDA	< MDA	< MDA	0.552 ± 0.144	160 ± 10
MB20	16-04-04	0.12 ± 0.03	0.24 ± 0.02	< MDA	< MDA	< MDA	0.505 ± 0.134	10 ± 10
MB21	16-04-04	0.07 ± 0.03	0.35 ± 0.03	< MDA	< MDA	< MDA	0.347 ± 0.138	100 ± 10
BH10	15-04-04	0.05 ± 0.03	0.03 ± 0.09	< MDA	< MDA	< MDA	< MDA	7150 ± 60
BHF	15-04-04	0.05 ± 0.02	0.17 ± 0.02	< MDA	< MDA	< MDA	< MDA	600 ± 20
OS2	-	-	-	-	-	-	-	-
OS3	15-04-04	0.06 ± 0.01	0.15 ± 0.01	< MDA	< MDA	< MDA	< MDA	1120 ± 20
CW	15-04-04	0.10 ± 0.03	0.10 ± 0.01	< MDA	< MDA	< MDA	0.308 ± 0.124	1140 ± 20
P1S	16-04-04	0.60 ± 0.12	0.30 ± 0.05	< MDA	< MDA	< MDA	0.275 ± 0.122	10 ± 10
P1D	16-04-04	0.35 ± 0.14	0.49 ± 0.12	< MDA	< MDA	< MDA	< MDA	200 ± 10
P2D	16-04-04	0.22 ± 0.09	1.08 ± 0.09	< MDA	< MDA	< MDA	0.613 ± 0.138	100 ± 10

Notes:
1. See Figure 4 for the location of the sampling piezometers.
2. OS 2 not sampled as piezometer was dry.
3. Gross beta results include the contribution from natural K-40.
4. < MDA indicates that the result was below the minimal detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 33. RADIOACTIVITY IN SEDIMENT, LHSTC STORMWATER BUNDS, July 2003 to June 2004

Location	Date Sampled	Gross Alpha (Bq/g DW)	Gross Beta (Bq/g DW)	Gamma-emitters (Bq/g DW)				
				Am-241	**Be-7**	**Cs-137**	**Co-60**	**K-40**
BUND A	11-6-04	0.18 ± 0.10	0.15 ± 0.02	< MDA	< MDA	< MDA	< MDA	0.086 ± 0.013
BUND B	11-6-04	0.28 ± 0.11	0.16 ± 0.02	< MDA	< MDA	< MDA	0.003 ± 0.001	0.053 ± 0.009
BUND C	11-5-04	0.49 ± 0.11	3.89 ± 0.04	0.003 ± 0.001	0.038 ± 0.010	0.156 ± 0.017	0.015 ± 0.002	0.182 ± 0.023
				Ce-144	**Ru-103**	**Ru-106**	**Zr-95**	**Nb-95**
BUND C Continued				0.488 ± 0.054	0.052 ± 0.006	0.871 ± 0.098	0.014 ± 0.003	0.040 ± 0.005

Notes:
1. See Figure 2 for the locations of the stormwater bunds.
2. DW - dry weight.
3. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 34. GAMMA DOSE-RATE SURVEY, LFBG TRENCHES, September 2003

Date of Survey	**Location**	**Dose-rate** (μSv/hour)
23 to 26-9-03	Background reading	
	(at LFBG gate)	0.08 – 0.18
	Trenches 1-51	0.06 – 0.19
	Trenches 52-77	0.07 – 0.20
	Trenches S1 and S2	0.09 – 0.16

Notes:
1. See Figure 4 for the location of the burial trenches and sampling points.

Table 35. GAMMA DOSE-RATE SURVEYS, MAIN DISCHARGE PIPELINE, LHSTC, July 2003 to June 2004

Date of Survey	**Location**	**Dose-rate** (μSv/hour)		**Background Dose-rate** (μSv/hour)
		Ground Below Joint	**Pipe Joint**	
18-9-03	Joints # 1-22	0.05 – 0.12	0.06 – 0.14	0.06 – 0.15
1-4-04	Joints # 1-22	0.07 – 0.12	0.07 – 0.11	0.08 – 0.15

Notes:
1. The survey excluded joints numbered 18 & 19 which are inaccessible.

Table 36. RADIOACTIVITY IN FISH, POTTER POINT AND THE ROYAL NATIONAL PARK, July 2003 to June 2004

Location	Date Sampled	Gamma-emitters in Blackfish (Bq/kg FW)					
		Be-7	**K-40**	**Am-241**	**Co-60**	**Cs-137**	**I-131**
Potter Point Ocean Outfall	22-10-03	< MDA	109 ± 11	< MDA	< MDA	< MDA	< MDA
	22-10-03	< MDA	107 ± 11	< MDA	< MDA	< MDA	< MDA
The Royal National Park Reference Site	5-12-03	< MDA	140 ± 14	< MDA	< MDA	< MDA	< MDA
	22-6-04	< MDA	136 ± 14	< MDA	< MDA	< MDA	< MDA

Notes for Tables 36, 37 and 38:

1. See Figure 1 for sampling locations at the Potter Point ocean outfall and the reference site. Duplicate samples were collected where possible.
2. The whole, unwashed samples of algae (*Ulva sp.*) and barnacle (*Tesseropera rosea*) were dried and ground prior to gamma spectrometry analysis. The fish, Luderick (*Girella sp.*), were cut into flesh fillets.
3. Fresh Weight (FW) Radioactivity is in units of becquerels per kilogram of fresh (wet) sample.
4. Be-7 and K-40 are of natural origin.
5. < MDA indicates that the result was below the minimum detectable activity, calculated with 95% confidence. Indicative (median) MDA values for various radionuclides and environmental media are listed in Table 1.

Table 37. RADIOACTIVITY IN ALGAE, POTTER POINT AND THE ROYAL NATIONAL PARK, July 2003 to June 2004

Location	Date Sampled	Gamma-emitters in Algae (Bq/kg FW)					
		Be-7	K-40	Am-241	Co-60	Cs-137	I-131
Potter Point Ocean Outfall	22-10-03 15-6-04	< MDA < MDA	191 ± 18 269 ± 26	< MDA < MDA	< MDA < MDA	< MDA < MDA	2.6 ± 0.3 5.1 ± 0.5
The Royal National Park Reference Site	5-12-03	6.1 ± 0.9	140 ± 17	< MDA	< MDA	< MDA	< MDA

Table 38. RADIOACTIVITY IN BARNACLES, POTTER POINT AND THE ROYAL NATIONAL PARK, July 2003 to June 2004

Location	Date Sampled	Gamma-emitters in Barnacles (Bq/kg FW)					
		Be-7	K-40	Am-241	Co-60	Cs-137	I-131
Potter Point Ocean Outfall	22-10-03 15-6-04	< MDA < MDA	21 ± 4 31 ± 7	< MDA < MDA	< MDA < MDA	< MDA < MDA	< MDA < MDA
The Royal National Park Reference Site	5-12-03 22-6-04	< MDA < MDA	16 ± 5 17 ± 4	< MDA < MDA	< MDA < MDA	< MDA < MDA	< MDA < MDA

Table 39. ESTIMATED EFFECTIVE DOSES FROM LHSTC AIRBORNE DISCHARGES, July 2003 to June 2004

Receptor Location	**2003-04 Estimated Effective Dose** (mSv/year)
Nearest resident	0.00260
LHSTC Library	0.00379
LHSTC Building 9	0.00425
LHSTC Main gate	0.00257
Stevens Hall Motel	0.00709
LH Waste Management Centre	0.00094
BMX track	0.00057
Woronora Valley	0.00058
At 1.6 kilometre radius from HIFAR	
NORTH	0.00369
NNE	0.00310
NE	0.00331
ENE	0.00382
EAST	0.00280
ESE	0.00164
SE	0.00187
SSE	0.00182
SOUTH	0.00123
SSW	0.00107
SW	0.00161
WSW	0.00135
WEST	0.00066
WNW	0.00061
NW	0.00117
NNW	0.00234
At 4.8 kilometre radius from HIFAR	
NORTH	0.00095
NNE	0.00055
NE	0.00075
ENE	0.00084
EAST	0.00059
ESE	0.00031
SE	0.00037
SSE	0.00042
SOUTH	0.00026
SSW	0.00024
SW	0.00037
WSW	0.00030
WEST	0.00014
WNW	0.00013
NW	0.00029
NNW	0.00059

Notes:
1. The annual effective dose at each compass point is estimated using stack discharges and concurrent meteorological data as input to the computer model, PC-Cream.
2. The annual dose limit for members of the public is 1 mSv/year (ARPANSA, 2002a).

Appendix A – Corrections to the Previous Report

Corrections for the previous report *Environmental and Effluent Monitoring at ANSTO Sites 2002-2003* (ANSTO E-752) are listed below:

- Page 15, Figure 2: TLDs number 3 and 5 were moved inside the HIFAR security fence in 2002 due to the construction of the RRR. The correct locations are shown in **Figure 2** of the current report (ANSTO E-755).
- Page 21, Section 6.3.2: The total volume of air sampled for January 2002 to June 2003 was 10,468 m^3, not 2617 m^3.
- Page 23, Section 6.4, first paragraph: The capacity of the stormwater bunds is at least 6 m^3, not 2 m^3.
- Page 35, References: In Hoffmann *et al.* (2001) the year, 2000, was omitted from the title.
- Page 59, Table 25: Standing water levels were given in centimetres rather than metres. The data should be divided by 100 to obtain the correct values.

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